AD-A038 380 DOD AIRCRAFT GROUND FIRE SUPPRESSION AND RESCUE OFFIC--ETC F/G 13/12
FLIGHT LINE EXTINGUISHER EVALUATION.(U)
JAN 77 G D CHAMBERS

UNCLASSIFIED DOD-AGFSRS-76-9 NL

| OF |
AD
A038380

END
DATE
FILMED
5-77

ADA038380

DOD-AGFSRS-76-9

11 NW

FLIGHT LINE EXTINQUISHER EVALUATION

AIR FORCE CIVIL ENGINEERING CENTER
TYNDALL AFB, FLORIDA 32401

JANUARY 1977

FINAL REPORT

Approved for public release; distribution unlimited

DOD AIRCRAFT GROUND FIRE SUPPRESSION AND RESCUE SYSTEM OFFICE
Wright-Patterson Air Force Base, Ohio 45433

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and that fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Reference to trade names is for information only and endorsement by the Department of Defense is not implied.

This report is approved for public release; distribution unlimited.

This Technical Report has been reviewed and approved.

Julius Singer

JULIUS SINGER, Program Manager
DOD Aircraft Ground Fire Suppression
and Rescue Office (AGFSRO)

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
14 1. REPORT NUMBER DOD-AGFSRS-76-9	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 Flight Line Extinguisher Evaluation.		9 5. TYPE OF REPORT & PERIOD COVERED Final Technical Report, Dec[redacted] 75 - Sep[redacted] 76
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Glen D. Chambers Major, USAF		8. CONTRACT OR GRANT NUMBER(s) P.O.FSMGF075P1196
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Civil Engineering Center (AFCEC) Tyndall AFB FL 32401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 64714F 12 93 p.
11. CONTROLLING OFFICE NAME AND ADDRESS DOD Aircraft Ground Fire Suppression and Rescue Systems Office (ASD/SMGF) Wright-Patterson AFB OH 45433		11 12. REPORT DATE Jan[redacted]77
		13. NUMBER OF PAGES 91
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Halon 1211, Bromochlorodifluoromethane, Fire Suppression Agent, CB-10 Flight Line Extinguisher, JP-4 Fuel Fires

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A two-phase test program was conducted to determine the optimum mechanical conversion of the FEU-1, CB-10 flight line fire extinguisher to enable it to utilize Halon 1211 (Bromochlorodifluoromethane) as the fire extinguishing agent instead of Chlorobromomethane (CB).

Phase I tests included static discharges to determine the optimum nitrogen pressurization and fill ratios for both an internally pressurized and externally pressurized configuration. Tests were also conducted to screen the most

over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

409 391

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

effective nozzles from a group of about sixteen to evaluate further on live fires during Phase II. The first phase also included tests to determine the area of fire likely to occur when various amounts of jet (JP4) fuel are spilled on a hard, flat surface.

Phase II included live fire tests using the nozzles, pressures and fill ratios selected as candidates in Phase I. After the completion of fire tests to determine the optimum combination of hardware using experienced operators, the effectiveness of the appliance in the hands of novice operators was also studied on simulated fuel spill fires as well as engine fires, tire fires, and three dimensional aircraft fires. Following the fire tests, the selected configurations were discharged after conditioning to tropic and arctic conditions to find out if the units were still operable and effective.

It was concluded that the FEU-1, CB-10 is an effective fire fighting appliance when mechanically converted to accommodate Halon 1211 as the fire extinguishing agent. It is recommended that existing units be converted to accommodate Halon 1211 by changing the filling mechanism and the discharge nozzle and letting the units remain in an internally pressurized configuration.

FOREWORD

This report describes the results of a study to evaluate the most cost effective conversion for existing Air Force CB-10 flight line extinguishers to employ Halon 1211 (Bromochlorodifluoromethane) fire suppression agent. The program was sponsored by the DOD Aircraft Ground Fire Suppression and Rescue Office (ASD/SMGF), Wright-Patterson AFB OH, under system 414N. Mr Richard Robbins was project monitor. The study was conducted by the Air Force Civil Engineering Center (AFCEC), Tyndall AFB FL, during the period December 1975 to September 1976.

The author wishes to acknowledge the extensive contributions of the Ansul Company and ICI United States to this program. The technical reports provided by these companies (at no cost to the government) formed the basis for this evaluation effort. The author also wishes to thank all companies that supplied Halon 1211 conversion kits and/or nozzles for use during this program. In addition, the author wishes to especially thank Mr Spencer Dunn, The Ansul Company, and Mr Jack Novotny, ICI United States, for their technical assistance.

The fire tests could not have been conducted at Tyndall AFB without the invaluable assistance of the base fire department. This department provided standby fire suppression support, use of equipment and personnel during all tests.

Last but not least, the author wishes to thank two Center personnel who participated throughout the program--TSgt Jerry T Reynolds, who did all the controlled fire fighting tests, and Major Rodger C Clarke for his photographic expertise.

CONTENTS

CONTENTS (CONT'D)

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF TABLES

1.0 INTRODUCTION

The major objective of this program was to determine the wheeled fire extinguisher configuration that is most cost effective for employment by non-fire fighters using Halon 1211 fire extinguishing agent against flight line type fires. Included objectives were to determine the optimum agent discharge pattern, extinguisher pressurization mode (internal or external) and flow rate and to quantitatively determine the amount of agent needed to extinguish typical flight line fires.

2.0 BACKGROUND

Bromochloromethane (CB) has been used as a fire extinguishing agent by the US Air Force in flight line extinguishers for many years. Equipment currently in service includes 10 and 20 gallon wheeled units that are positioned near parked aircraft. These units are usually considered a first aid type appliance to be used by relatively untrained (in fire fighting) personnel to extinguish incipient fires faster than fire department vehicles can arrive with primary extinguishing agents like foam and massive quantities of water.

Because CB has irritating and toxic effects, it has been excluded from the list of acceptable fire extinguishing agents by the Occupational Safety and Health Administration (OSHA). In searching for a replacement, it was found that a report published by the Aircraft Ground Fire Suppression and Rescue Office,[1] ASD-TR-73-41, indicated that bromochlorodifluoromethane (Halon 1211) was clean and more effective on aircraft engine/nacelle fires. Recent reports by The Ansul Company[2] and by ICI United States Inc[3] also confirmed the feasibility of converting CB-10 units to

accommodate Halon 1211 at a large cost savings when compared to the purchase of new extinguishers of comparable fire fighting effectiveness. There is also precedence for such a conversion since larger CB extinguishers were removed from obsolete P-6 ramp patrol vehicles and converted to Halon 1211 systems for use on P-13 fire trucks.

A clean agent is defined as a fire suppression product that does not leave a residue in the fire area or on adjacent parked aircraft. For example, dry chemical or foam residues are extremely difficult to remove completely from intricate aircraft or electronic components. Yet they must be meticulously cleaned to prevent subsequent corrosion and possible malfunctions, especially on electronic equipment. For example, estimates to overhaul an aircraft engine after the discharge of a fire extinguishing agent vary from $4,000 for a U-3A engine to $145,000 for a C-5 engine with the most representative cost in the range of $40,000 to $60,000. Employment of a clean agent like Halon 1211 might significantly reduce associated overhaul maintenance costs.

Halon 1211 is a chemically pure liquified gas that vaporizes almost instantly upon application, leaving no residue. In this respect, it is the only clean agent judged suitable for use in flight line extinguishers that is recognized as acceptable by regulatory agencies, including OSHA, the National Fire Protection Association (NFPA), Underwriters Laboratories (UL), and the US Coast Guard.

3.0 DETAILED OBJECTIVES

3.1 Phase I Objective

The objective of Phase I was to determine the optimum wheeled

fire extinguisher configuration(s) for further testing on live fires in Phase II. It is known that Halon 1211 has different physical properties than CB and, therefore, requires different filling mechanisms, nozzles, nitrogen pressurization, etc. ICI had reported that it was possible to convert existing CB units by simply replacing the existing CB nozzle and replacing the existing filling cap with a modified cap that permitted a closed liquid transfer for Halon 1211[3]. Ansul had reported similar success with internally pressurized units but recommended a more extensive conversion to external pressure to enable the units to hold considerably more agent and hence be a more effective fire fighting appliance[2].

There are many variables that influence the discharge pattern and, therefore, the effectiveness of a fire extinguisher. The pattern itself must also be a compromise between a long narrow stream that is effective where considerable range is needed, like high aircraft engines, and a shorter, wider, softer pattern for spill and running fuel fires. It is possible to construct a variable pattern or adjustable nozzle like the one currently employed on the CB-10 which delivers a straight stream, a dispersed pattern or a fog of agent. Employment of this variable CB nozzle has shown that novice fire fighters are usually not prepared to make the correct choice during emotional stress that accompanies the outbreak of a fire. It is, therefore, highly desirable to have a fixed nozzle that is effective on the fires most likely to occur on the flight line.

The following variables were evaluated during Phase I:

1. <u>Extinguishers' Pressurization Mode</u>: Internally pressurized extinguishers need considerable space in the agent tank for

nitrogen pressure. Since the pressure is continually dropping as the agent leaves the tank, the flow rate and range drop off throughout the discharge. Externally pressurized extinguishers require a separate high pressure nitrogen source, a pressure regulator and associated piping. With this method, considerably more agent can be contained in the tank and the regulated pressure source enables fairly constant range and flow rate throughout the discharge.

2. Nozzle Configuration: Nozzle design influences discharge pattern and the diameter/length of the orifice or throat affects the flow rate. The nozzle can also be flattened to widen the pattern in one plane to make it more effective on fuel spill type fires but less effective where long range is needed.

3. Fill Ratio: This parameter is influenced by the method of pressurization. With internally pressurized units, ICI reported that a 55% liquid fill ratio was optimum with the remaining 45% of the tank volume left for nitrogen[3]. With external pressurization, the controlling variable is temperature since some space must be left for liquid expansion to prevent hydraulic pressure and bursting of the tank. ICI reported that a fill of 85% would not become liquid full even at temperatures up to 155°F[3].

4. Amount of Nitrogen Pressure: This variable influences flow rate and, therefore, total discharge time, pattern (i.e.,

liquid range and agent plume), and the amount of agent that is discharged before flashing or sputtering occurs. Pressure drops occur across the hose and nozzle so the pressurization must be carefully matched to the hardware to provide optimum fire extinguishing effectiveness. With internal pressurization, around 200 psi or higher is normally optimum with Halon 1211, depending on the length and diameter of the hose. With external pressure, less than 200 psi is normally sufficient, again depending on friction losses across the hose and nozzle[3].

5. Amount of Fire Resulting from Various Fuel Spills: This information was needed to determine the fire sizes for Phase II and to help select the most cost effective conversion. It is known that a very high percentage of flight line fuel spill fires involve small amounts of fuel. It was, therefore, necessary to determine the fire area likely to result from this type of spill. This is also helpful because it is known that one pound of Halon 1211 is capable of extinguishing approximately five square feet of fire built to UL conditions per standard #711 when tested in smaller appliances like hand portables. No attempt was made to correlate UL or fuel-in-depth fires with simple fuel spills on a hard surface. However, it is known that fuel-in-depth fires require considerably more agent to extinguish than a spill of the same area.

3.2 Phase II Objective

The objective of the second phase was to validate the selection

of extinguisher configuration and nozzle design selected in Phase I. Test fires simulated fuel spills on a flat (level) concrete surface, pooled fuel-in-depth fires, engine fires, tire fires, and obstructed and running fuel fires. The most promising configurations were tested to determine severe temperature effects at the Climatic Laboratory, Eglin AFB FL.

3.2.1 Spill Fires (Concrete)

Test fires were conducted on a flat concrete surface. A specified quantity of fuel (JP-4) was spilled onto the surface and allowed to spread for 120 seconds, at which time the area was estimated and the fuel ignited. A preburn of only 15 seconds was allowed prior to agent application to insure the fuel was not consumed before the test was completed.

3.2.2 Fuel Spill Fires (Pool)

Test fires were conducted on a concrete surface, sloped to allow circular fires varying in diameter from 15 feet to 50 feet. Diameter and surface area were changed by adding or removing water on which the fuel floated. A sufficient quantity of fuel was added to allow for a 60-second preburn and to insure the fuel was not consumed before the test was completed.

3.2.3 Engine Fires

Aircraft engine fires are usually obstructed by vanes or other airframe parts so that the agent must have the ability to penetrate into obscured areas. AGFSRS[1] reported that Halon 1211 was the most effective agent of those tested on this type of fire. During this program, running fuel was fed into the engine compartment of a salvaged T-33 aircraft and was allowed a preburn. Halon 1211 was then injected into the air intake

and/or the exhaust from a converted CB-10 unit.

3.2.4 Tire Fires

These tests were conducted on complete aircraft wheel and tire assemblies. The tires (non pressurized) were given various preburns above a tray of JP-4 and/or gasoline mixture and tests were conducted with Halon 1211, dry chemical and CB. Extinctions were observed for reignition or other problems like cracking or explosion of the metal wheels.

3.2.5 Obstructed and Running Fuel Fires

These tests were also conducted on the salvaged T-33 aircraft in conjunction with engine fires. Fuel was allowed to flow into the interior of the aircraft at such a rate that it could not be completely consumed by the fire. Excess fuel dripped to the ground from cracks in the fuselage and around concrete support pillars.

3.2.6 Novice Trials

Hardware evaluation tests were conducted using an experienced operator to minimize variables in fire fighting techniques. Following these tests, novices were allowed to approach different fire situations without instructions or protective clothing. Their performance was used to help select the most cost effective conversion.

3.2.7 Climatic Conditioning

At the completion of live fire tests, the chosen units were conditioned at the DOD Climatic Laboratory at Eglin AFB FL for 24 hours to $-60^{o}F$ temperature to simulate severe arctic conditions and then discharged to observe any changes in pattern, flow rate, etc. The units were then conditioned to $140^{o}F$ and discharged to simulate severe tropic or desert

conditions.

4.0 PHASE I

4.1 Hardware Configuration Evaluation

Tests conducted during this phase were intended to evaluate nozzle design and the resulting discharge range and pattern as influenced by the nitrogen pressure and fill ratio. Systems judged to be the most effective from a fire fighting and practical viewpoint were evaluated on live fires in Phase II.

It should be pointed out that some of the observations taken during these tests are subject to individual interpretation and are often a matter of personal judgment. Likewise, some readings like pressure, range, etc, are continually varying, so some error is inherent. However, every possible precaution was taken to ensure data that is valid.

4.2 Method of Testing Nozzles

4.2.1 Pattern

To quantitatively evaluate each nozzle for range and stream width, wooden stakes were spaced at one foot intervals in a straight line for 50 feet. Near the center, stakes were placed at one foot intervals perpendicular to the 50 foot line and extending a few feet on either side. Photographers were positioned perpendicular to the long dimension to observe the range from a test nozzle held at zero feet and behind the operator and test nozzle to observe the width of the discharge stream. (See Figure 1)

4.2.2 Pressures

All nozzle tests were conducted using an externally pressurized

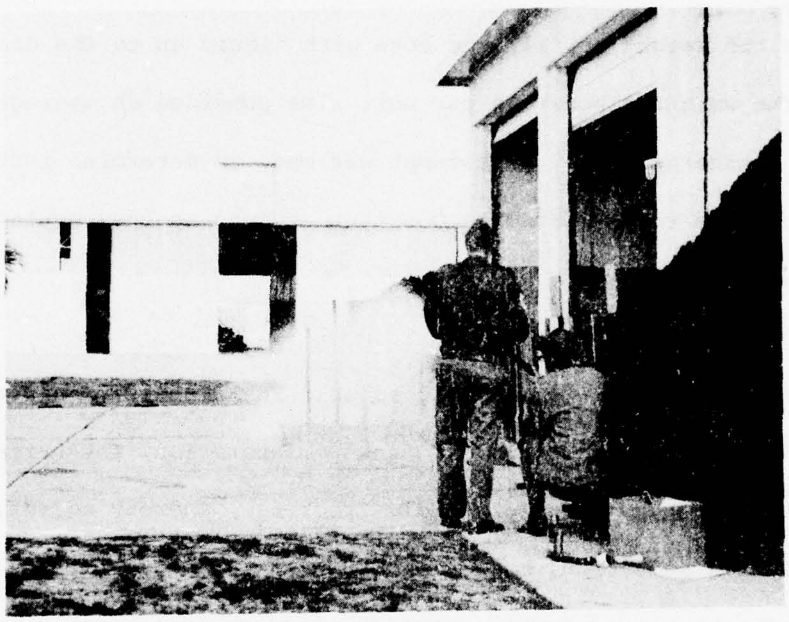


FIG. 1 RANGE TEST APPARATUS

converted CB-10 extinguisher. This procedure was used to conserve agent and time while allowing consistent test data. Nitrogen was supplied from a high pressure cylinder (1600 psi) through a regulator that was set at the desired test pressure. A pressure gauge was mounted in a "T" fitting just behind the test nozzle.

4.2.3 Discharge Rate

During each test, the entire CB-10, with the exception of the hose and nozzle, was positioned on a large scale. Initial weights were recorded as well as the weight to fill the hose with liquid up to the discharge nozzle. The weight discharged per unit time provided an average flow over the total discharge time. No attempt was made to determine instantaneous rates, since the rates should be constant as long as the regulator pressure was constant.

4.2.4 Nitrogen Solubility

Since nitrogen is somewhat soluble in Halon 1211, all tests were conducted with saturated agent. To ensure saturation, the extinguisher handle was raised and lowered rapidly (rocking), thereby agitating the liquid. During agitation, makeup nitrogen was added to replace the amount dissolved in the liquid. This procedure was repeated until the nitrogen pressure was in equilibrium.

4.2.5 Wind Effects

Wind gusts can affect visual observations of discharge pattern, especially range and plume formation. To eliminate this problem, all Phase I static discharge tests were conducted when winds were essentially zero with a maximum allowable breeze of 3 mph.

At the test site (Tyndall AFB), these wind conditions are available for a short time after sunrise each morning. However, at this time, the relative humidity is near 100%. Halon 1211 evaporation caused some chilling of air around the discharge causing condensation in the form of visible moisture or fog. This fog was at times difficult to distinguish from agent vapor causing some error in judging plume formation. However, this error is considered slight and inconsequential when compared to the benefits of zero wind.

4.2.6 Observation Criteria

4.2.6.1 Pressure Readings

Since the line pressure of compressed gas regulators is dependent on the back pressure and back pressure varied with each test nozzle, the possibility of adjusting the nitrogen regulator back to the set test pressure during discharge was considered. However, this was judged to be unnecessary since the maximum change noticed at lower pressures was about 5 psi. The pressure gauge behind the nozzle also fluctuated slightly during discharge, usually plus or minus a few psi. The final reading for Pn was taken as the technicians' judgment of the average pressure over a 10-second interval.

4.2.6.2 Range Readings

These readings were taken at the point where liquid Halon 1211 hit the ground. In cases where the agent evaporated completely in the air, the point where the visible continuous plume ended (gaps appeared) was taken as the range.

4.2.6.3 Pattern Quality

This observation was the judgment of the test conductor as to the fire fighting effectiveness of the discharge and would be verified in Phase II. Some typical examples are shown in Figures 2 and 3.

4.3 Nozzles Tested

Nozzle design is critical on a fire extinguisher because its configuration determines the discharge pattern and the diameter/length of the orifice or throat has a big effect on flow rate. To evaluate all possible yet practical configurations, 16 nozzles were selected for initial test from a group supplied by several different companies involved in fire extinguishing products.

4.3.1 Ansul (0.422 Inch Orifice)

A brass nozzle with a horseshoe shaped lever to actuate the valve, which is an integral part of the nozzle (Figure 4).

4.3.2 Ansul (0.522 Inch Orifice)

Same as 4.3.1 but with a larger orifice to permit higher flow rates (Figure 4).

4.3.3 CB-10 Nozzle

This is a three position nozzle used on the CB-10 and was evaluated with Halon 1211.

4.3.4 Feecon

Pistol grip nozzle with variable pattern control (Figure 5).

4.3.5 Graviner

This is a commercially available nozzle used on Halon 1211 wheeled units of smaller agent capacity than that intended for the CB-10.

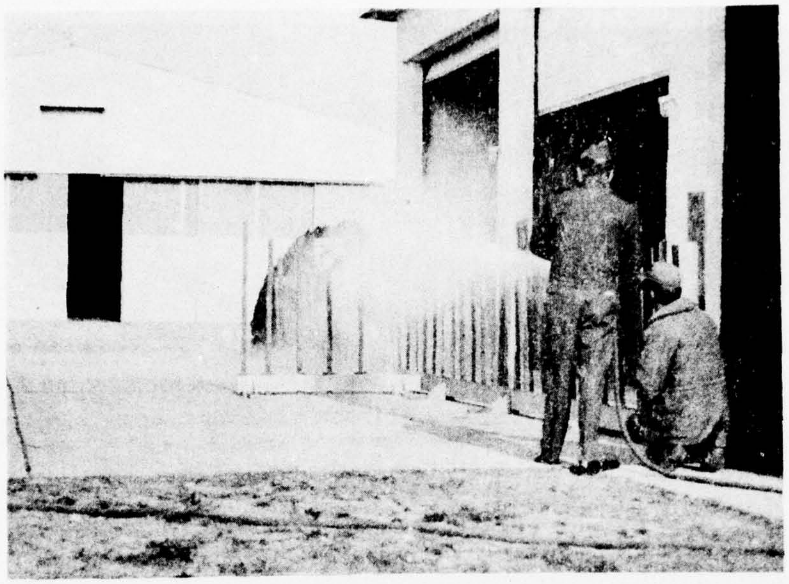


FIG. 2 DISCHARGE PATTERN EVALUATION

FIG. 3 DISCHARGE PATTERN EVALUATION

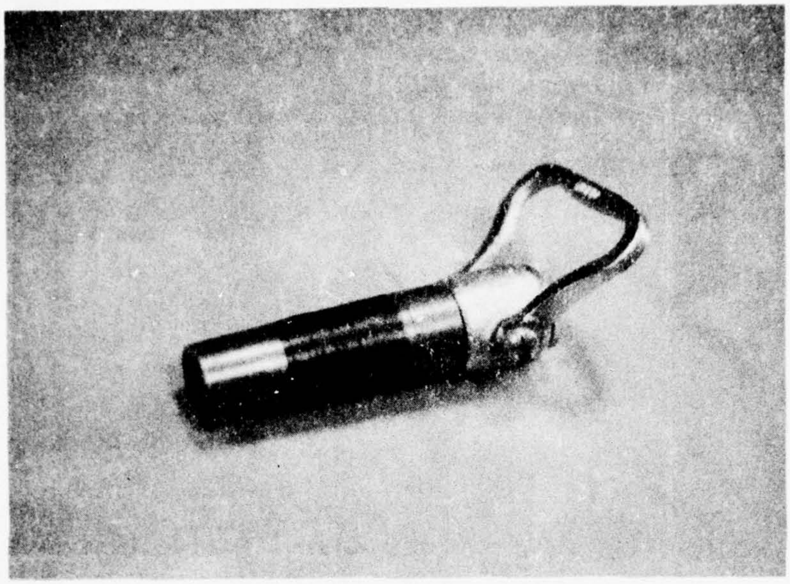


FIG. 4 ANSUL NOZZLE

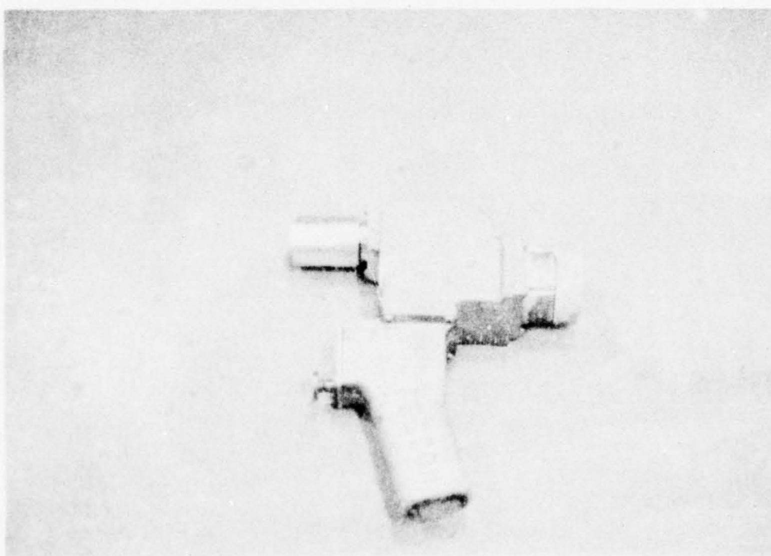


FIG. 5 FEECON NOZZLE

The actual nozzle could be removed from the valve mechanism by a quick disconnect to attach an extendable applicator or probe. The operating lever was under and parallel to the valve so that it resembled the nozzle used on gasoline pumps. (Figure 6)

4.3.6 <u>ICI Plastic</u>

A converging-diverging nozzle without an integral valve. This type is used extensively on Halon 1211 wheeled units in Europe and elsewhere for aircraft protection. (Figure 7)

4.3.7 <u>ICI Fans</u>

A brass, flattened horn without an integral valve. These types of nozzles spread the agent in one plane and are sometimes considered more effective than circular nozzles on flat surface fires when held horizontally. Because it spreads the agent, range is usually reduced. Three sizes were evaluated. (Figure 7)

4.3.8 <u>Stop Fire Fans</u>

Same as 4.3.7 of different sizes. Two units were evaluated. (Figure 8)

4.3.9 <u>Stop Fire Conical</u>

Same type as 4.3.6. Three units were evaluated. (Figure 8)

4.3.10 <u>Rockwood</u>

Long horn with integral valve that could be set for straight stream or dispersed pattern. (Figure 9)

4.3.11 <u>Wilco</u>

Plastic nozzle with variable pattern control. (Figure 9)

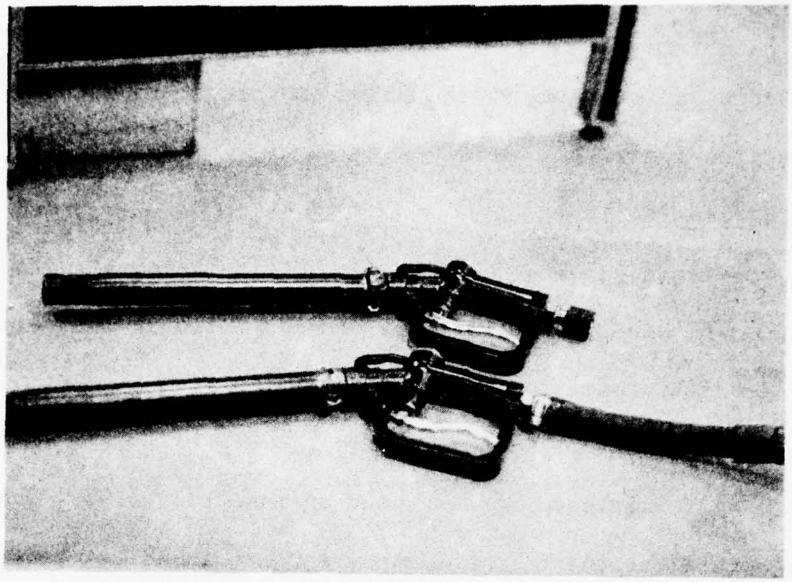


FIG. 6 GRAVINER NOZZLE

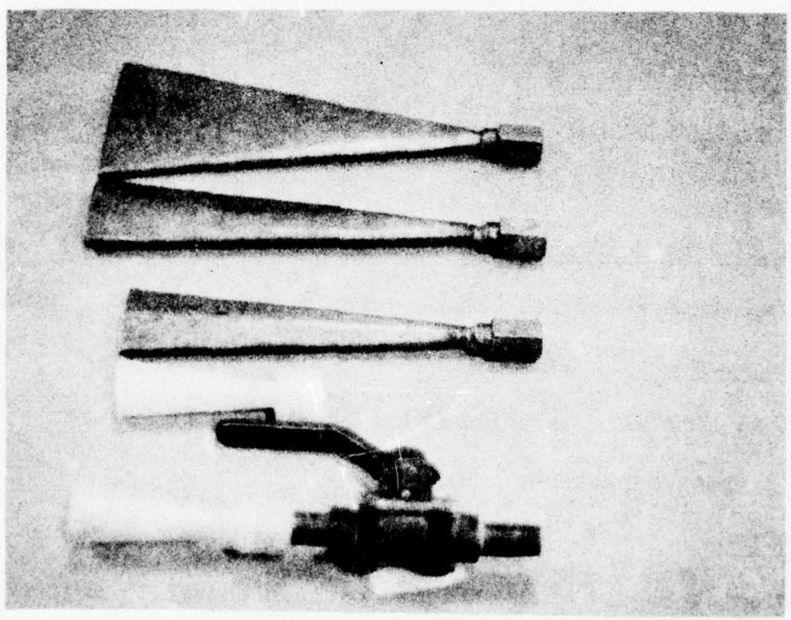


FIG. 7 ICI NOZZLES

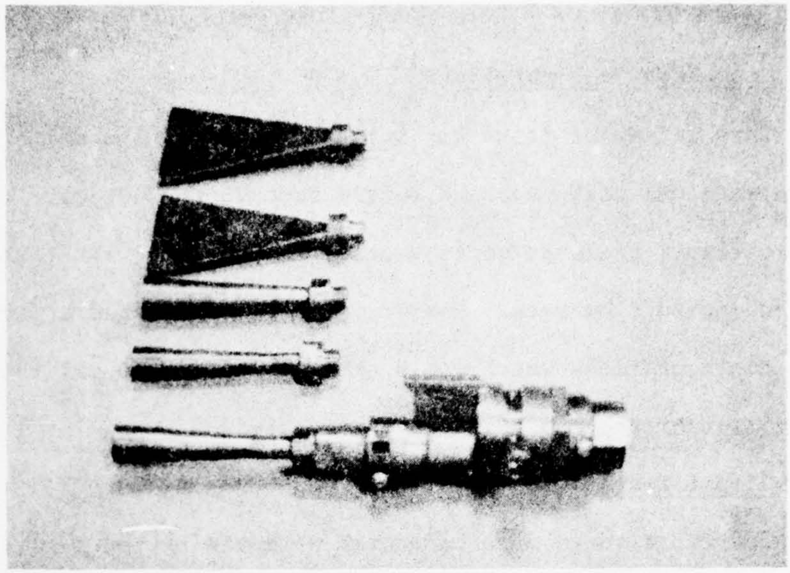


FIG. 8 STOP FIRE NOZZLES

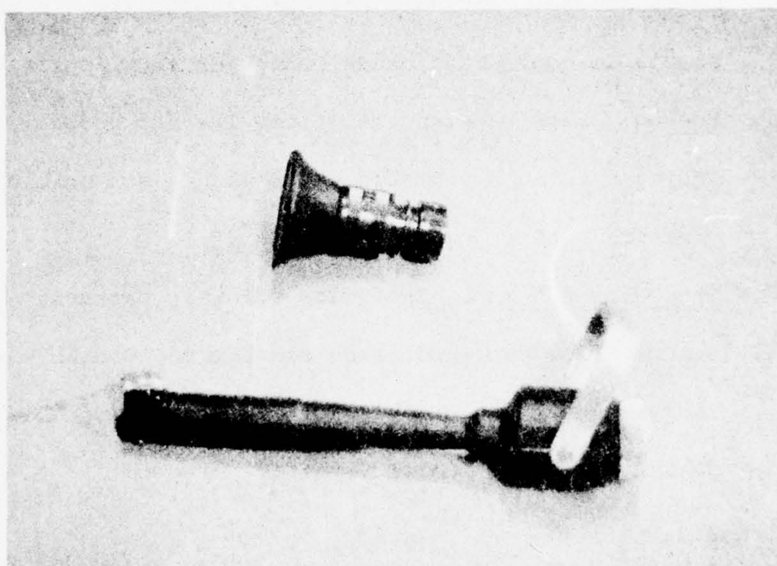


FIG. 9 WILCO (TOP) AND ROCKWOOD (BOTTOM) NOZZLES

4.4 Discharge Test Results

This series of tests was intended to determine which nozzles were effective when the tank pressure ranged from 75 to 200 psi. The tests used only the external pressure configuration to prevent evaluation of a continually changing flow rate. However, the results would apply to internal pressure configurations which would start at about 200 psi then drop to about 75 psi near the end of the agent supply.

4.4.1 75 psi Tests

The first tests were conducted with the nitrogen regulator set at 75 psi. The results are shown in Table I. Of the 16 nozzles evaluated, 4 were rejected, as follows:

1. CB-10 Nozzle: Intended for comparison only. A multiposition nozzle is considered undesirable for this application.
2. Feecon: Flow rate and range too low and probably would not increase to an acceptable level with a reasonable increase in pressure.
3. Stop Fire #15 Fan: Excessive voids in pattern. (See Fig. 3)
4. Wilco: Flow rate and range too low and probably would not increase to an acceptable level with a reasonable increase in pressure.

4.4.2 150 psi Tests

After discharges with the nitrogen regulator set at 150 psi (Table II), the following nozzles were also rejected:

1. Graviner: Poor liquid range.
2. ICI Smallest Fan: Stream too compact, poor range.

TABLE I

EXTERNAL NITROGEN PRESSURE TEST

75 psig

NOZZLE	FLOW RATE (LBS/SEC)	ΔP HOSE	P_n *	RANGE (FT)	OBSERVATIONS	EVALUATE FURTHER
ANSUL .422	3.3	20	55	25	GOOD PLUME	YES
ROCKWOOD (ST STREAM)	2.4	19	56	25	SOLID, COMPACT STREAM	YES
ROCKWOOD (DISPERSED)	2.5	25	50	15-20	NICE PLUME - LACKED RANGE	NO
WILCO (ST STREAM TO DISPERSED)	1.4	15	55	5-10	POOR - FLOW RATE TOO LOW	NO
WILCO (ST STREAM)	1.7	19	56	25	COMPACT STREAM - FLOW RATE LOW	NO
ICI PLASTIC	3.5	15	60	25-30	GOOD STREAM	YES
ICI SMALLEST FAN (HORIZONTAL)	3.0	38	37	25-30	COMPACT SOLID STREAM	YES
ICI SMALLEST FAN (VERTICAL)	3.3	35	35	25-30	COMPACT SOLID STREAM	YES
ICI MIDDLE FAN (HORIZONTAL)	3.0	39	32	25-30	COMPACT STREAM	YES
ICI MIDDLE FAN (VERTICAL)	3.1	35	35	25-30	LOOKED SOFT	YES
ICI LARGEST FAN (HORIZONTAL)	3.4	30	40	25	PULSATING PATTERN	YES
ICI LARGEST FAN (VERTICAL)**	3.1	30	35	20	PULSATING PATTERN	YES
STOP FIRE #10 CONICAL	2.1	20	55	25-30	COMPACT STREAM - LOOKED SOFT	YES
STOP FIRE #6 CONICAL	3.2	35	40	30	COMPACT STREAM	YES
STOP FIRE #1 CONICAL	3.2	35	40	25-30	COMPACT STREAM	YES
STOP FIRE #15 FAN (HORIZONTAL)	2.6	45	30	22	SOFT STREAM - EXCESSIVE VOIDS	NO
STOP FIRE #1 FAN (HORIZONTAL)	3.1	35	35	18-22	EXTREMELY WIDE PATTERN	YES
STOP FIRE #1 FAN (VERTICAL)	3.1	35	35	22	EXTREMELY WIDE PATTERN	YES
FEECON (ST STREAM)	0.35	5	70	5	EXTREMELY POOR	NO
GRAVINER	3.6	40	30	25-30	COMPACT STREAM - LOOKED GOOD	YES
CB NOZZLE (ST STREAM)	4.1	38	37	15-20	EXTREMELY WIDE PATTERN	NO
CB NOZZLE (DISPERSED)	4.2	40	35	20	EXCESSIVE AGENT VOIDS	NO
CB FOG	4.1	40	30	5-12	SOLID/WIDE PATTERN - POOR RANGE	NO
ANSUL .522	4.5	60	15	25-30	GOOD PLUME	YES

*AVERAGE OVER 10 SECONDS.
**EXTINGUISHER RAN OUT OF AGENT NEAR END OF TEST.

3. ICI Medium Fan: Stream separated into two parts with the center void.

4. ICI Largest Fan: Stream separated into two parts with the center void.

5. Stop Fire #6 Conical: Range too short.

6. Stop Fire #10 Conical: Low flow rate.

4.4.3 125 psi Tests

The only nozzle rejected after this test was Stop Fire #1 Fan, which had a wide, dispersed plume with too little agent to be effective on live fires (see Table III). Since this nozzle had been judged the best of the fan type, it was decided to conduct one live fire to record effectiveness.

4.4.4 100, 200 and 175 psi Tests

No nozzles were rejected (see Table III). The Rockwood nozzle was evaluated further during Phase II. The Stop Fire #1 Conical performed well throughout this series, but it was not evaluated further since it was physically very similar to the ICI plastic nozzle and further test results should apply to both nozzles.

4.5 CB Comparisons

Static discharge tests were conducted with an unmodified CB-10 using CB as the agent to provide a basis for comparison. The results of complete discharges with the nozzle set at its three different positions are shown in Table IV. With the nozzle in the straight stream position, there was very little change in range throughout the entire discharge. In the dispersed position, the pattern was too wide, and it appeared the agent

TABLE 11

EXTERNAL NITROGEN PRESSURE TEST

150 psig

NOZZLE	FLOW RATE (LBS/SEC)	ΔP HOSE	P_n *	RANGE (FT)	OBSERVATIONS	EVALUATE FURTHER
ANSUL .422	6.1	85	60	25-30	GOOD PLUME	YES
ROCKWOOD (ST STREAM	4.6	50	100	25	SOLID, COMPACT PATTERN	YES
ICI PLASTIC	5.4	75	70	30	GOOD, COMPACT PATTERN	YES
ICI SMALLEST FAN (HORIZONTAL)	4.5	55	80	20	COMPACT STREAM - POOR RANGE	NO
ICI SMALLEST FAN (VERTICAL)	4.7	62	75	20	COMPACT STREAM - POOR RANGE	NO
ICI MIDDLE FAN (HORIZONTAL)	5.2	75	70	25-30	COMPACT STREAM	NO
ICI MIDDLE FAN (VERTICAL)	5.4	85	65	25	STREAM SEPARATED WITH CENTER VOID	NO
ICI LARGEST FAN (HORIZONTAL)	4.7	72	78	20	COMPACT STREAM	NO
ICI LARGEST FAN (VERTICAL)	4.7	85	65	15-20	STREAM SEPARATED WITH CENTER VOID	NO
STOP FIRE #6 CONICAL	5.1	75	65	10-15	LARGE PLUME - POOR RANGE	NO
STOP FIRE #1 CONICAL	5.9	90	50	20	POOR RANGE	YES
STOP FIRE #1 FAN (HORIZONTAL)	4.7	70	65	25	GOOD PLUME	YES
STOP FIRE #1 FAN (VERTICAL)	5.2	70	65	25	GOOD PLUME	YES
GRAVINER	5.6	100	50	10-20	POOR LIQUID RANGE	NO
ANSUL .522	6.7	95	55	25-30	GOOD, WIDE PLUME	YES
STOP FIRE #10 CONICAL	4.3	45	105	25-30	LOW FLOW RATE	NO

*AVERAGE OF 10 SECONDS.

TABLE III

EXTERNAL NITROGEN PRESSURE TEST

125 psig

NOZZLE	FLOW RATE (LBS/SEC)	ΔP HOSE	P_n*	RANGE (FT)	OBSERVATIONS	EVALUATE FURTHER
ANSUL .422	4.5	75	35	25	GOOD PLUME	YES
ROCKWOOD (ST STREAM)	2.8**	20	85	25	COMPACT STREAM	YES
ICI PLASTIC	4.6	50	65	30	GOOD SOLID STREAM	YES
STOP FIRE #1 CONICAL	4.5	65	55	25	GOOD PLUME	YES
STOP FIRE #1 FAN (HORIZONTAL)	4.7	60	65	22	PLUME TOO WIDE	NO
STOP FIRE #1 FAN (VERTICAL)	4.7	60	60	22	PLUME TOO WIDE	NO
ANSUL .522	5.7	75	50	22	GOOD PLUME	YES
			100 psig			
ICI PLASTIC	4.2	45	55	30	GOOD SOLID STREAM	YES
ROCKWOOD (ST STREAM)	3.3	20	80	25-30	COMPACT SOLID STREAM	YES***
ANSUL .522	4.7	70	25	30	GOOD PLUME	YES
ANSUL .422	4.6	50	40	30	GOOD PLUME	YES
			200 psig			
ICI PLASTIC	6.7	100	105	35-40	GOOD SOLID STREAM	YES
ANSUL .422	6.5	125	75	35-40	VERY GOOD PLUME	YES
			175 psig			
ANSUL .422	6.3	80	95	35-40	VERY GOOD	YES
ICI PLASTIC	5.8	80	95	35-40	VERY GOOD	YES

*AVERAGE OF 10 SECONDS.
**DATA QUESTIONABLE.
***EVALUATED DURING PHASE II ON LIVE FIRES.

was spread too thin. In the fog position, the liquid dropped continually to the ground from 10 to 35 feet.

TABLE IV

CB TESTS - INTERNAL PRESSURE*

NOZZLE	FLOW RATE** (LBS/SEC)	RANGE (FT)	TOTAL DISCHARGE TIME (SEC)	OBSERVATIONS
ST STREAM	6.7	20-25	23	NO DROP-OFF IN RANGE.
DISPERSED	6.8	28***	22	PATTERN TOO WIDE; AGENT APPEARED THIN.
FOG	6.0	10-35***	25	LIQUID DROPPED CONTINUALLY TO GROUND BETWEEN 10 AND 35 FT.

*INTERNAL PRESSURE WAS 240 psi.

**AVERAGE OVER FIRST TEN SECONDS.

***DISPERSED/FOG SETTINGS, RAISED STREAM TRAJECTORY CAUSING INCREASED RANGE.

4.6 Discussion of Discharge Evaluations

Sixteen nozzles were evaluated by static discharge tests for quality and effectiveness of pattern and for flow rate. Nozzles that could not produce a flow rate high enough to be effective on live fires were rejected immediately (4.5#/sec at or greater than 150 psig). As the tank pressure was changed, it became apparent that fan shaped nozzles either had poorer range than conical nozzles or they had voids and gaps in the pattern and were, therefore, rejected. The Ansul 0.422 appeared to have the most consistent, high quality pattern and the least change in flow rate throughout

the desirable pressure range (see Figure 10). Similarly, the converging-diverging nozzles like the ICI Plastic and the Stop Fire #1 Conical maintained consistent quality, but the flow rate changed more in the 125 to 200 psi range. The ICI Plastic nozzle was included for further evaluation since it has the advantage of lower cost when compared to brass, and there is less likelihood of pilferage in the field.

4.7 Fill Ratio Tests (Internal Pressure)

The purpose of this test series was to confirm the ICI data which showed that a 55% fill density (62.7 lb/cu ft) was optimum for internally pressurized units. It should be noted that these tests were intended only to spot-check a few fill densities with only one nozzle (ICI Plastic).

With the internal pressure configuration, the combination of nitrogen pressure, friction in the hose, nozzle back pressure and agent fill density determine the amount of usable discharge time. Usable discharge time is defined as the period of output or flow before voids appear (flashing). After severe flashing occurs, the fire fighter would probably lose control of the fire in all but complete overkill situations.

Flashing is usually attributed to the release of dissolved nitrogen from the agent while it is passing through the hose. The nitrogen collects into large bubbles, and when the bubble reaches the nozzle there is a momentary interruption of liquid flow. The tendency for nitrogen to be released in the hose is dependent on the pressure and the residence time in the hose. As the pressure drops, more nitrogen is released.

Pressure drop is determined by the initial tank pressure and the agent fill density, assuming the hose will remain constant or will not be

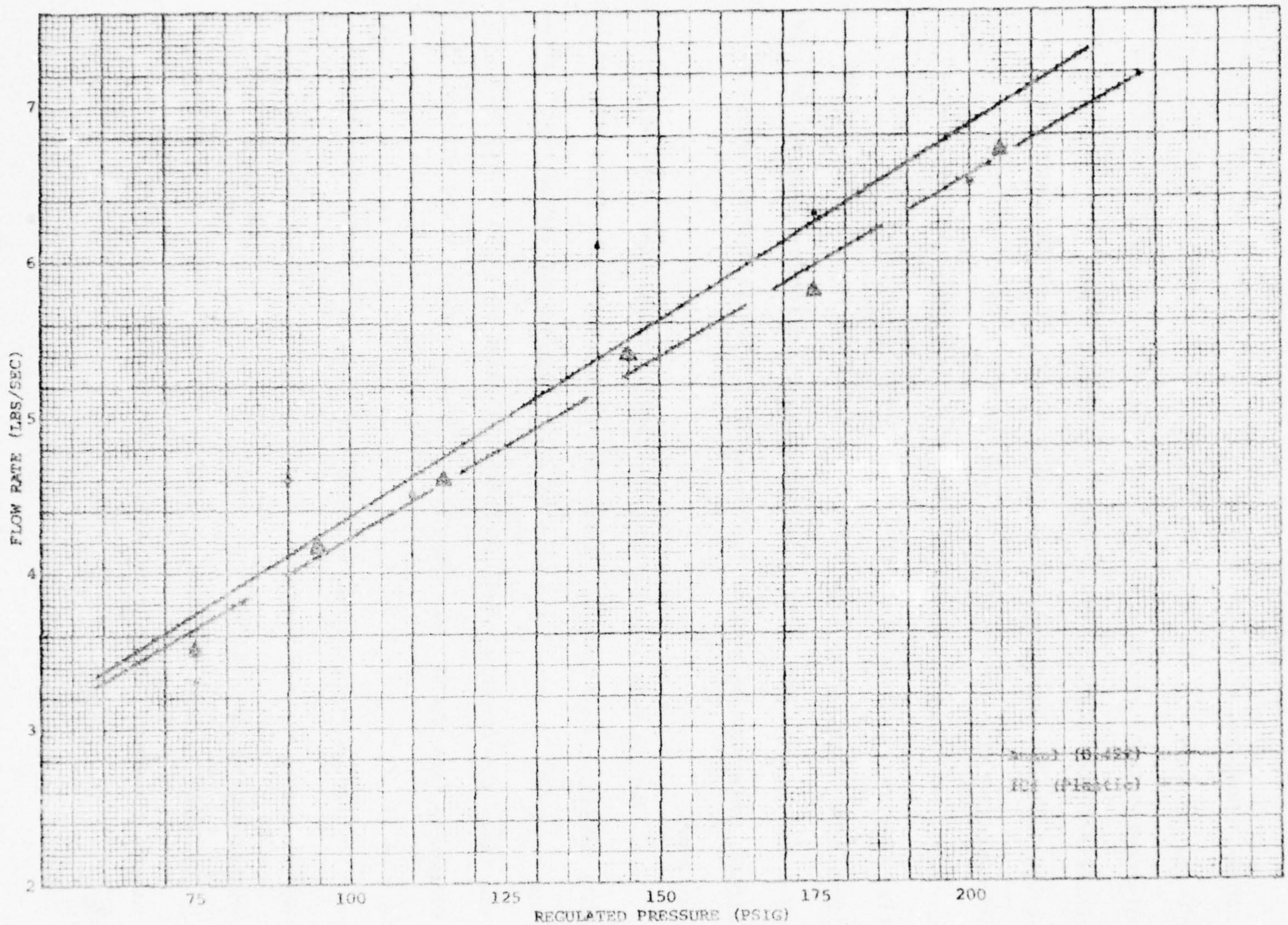


FIG. 10 FLOW RATE VERSUS REGULATED PRESSURE

changed. However, since the maximum initial pressure is limited to the 200-240 psi range by the strength of the tank, the rupture disc, etc, the only controllable variable is the agent fill density. With high fill densities, more agent is available for fire fighting, but a smaller volume is available for nitrogen. As the agent flows out of the reservoir, the nitrogen pressure drops rapidly to a point where two phase flow occurs in the hose. With lower agent fill densities, less agent is available for fire fighting, but the pressure drop is considerably less and there is less likelihood of two phase flow until almost all the agent is discharged. It should be pointed out that it is impossible to discharge 100% of the agent without interruption because approximately 17 lbs is needed just to fill the hose.

During this test series, internally pressurized units with various fill densities were completely discharged to observe the point where flashing occurred. A record was kept of weight discharged versus time. After the test, the weight discharged before flashing could be determined from a weight vs time graph. The results are shown on Table V and plotted on Figure 11.

It was noticed during these tests that where the flashing point occurs during the discharge was often difficult to pinpoint accurately (either during the test or by reviewing the film). In some tests, there were a few short flashes followed by a resumption of continuous flow and then severe flashing. These questionable tests are not included in Table V.

4.7.1 Conclusions

It was observed that test results of agent fill densities around

TABLE V

FILL DENSITY TESTS

TEST NO.	FILL DENSITY	FLASHING (SEC)	% DISCHARGED BEFORE FLASHING
62	56% (126 lbs)	25	87% (109 lbs)
63	59% (135 lbs)	24	73% (98 lbs)
66	50% (113 lbs)	27	88% (100 lbs)
60	65% (148 lbs)	22	57% (85 lbs)
73	56% (126 lbs)	21	77% (97 lbs)
75	50% (115 lbs)	25	82% (94 lbs)
79	70% (160 lbs)	23	59% (95 lbs)

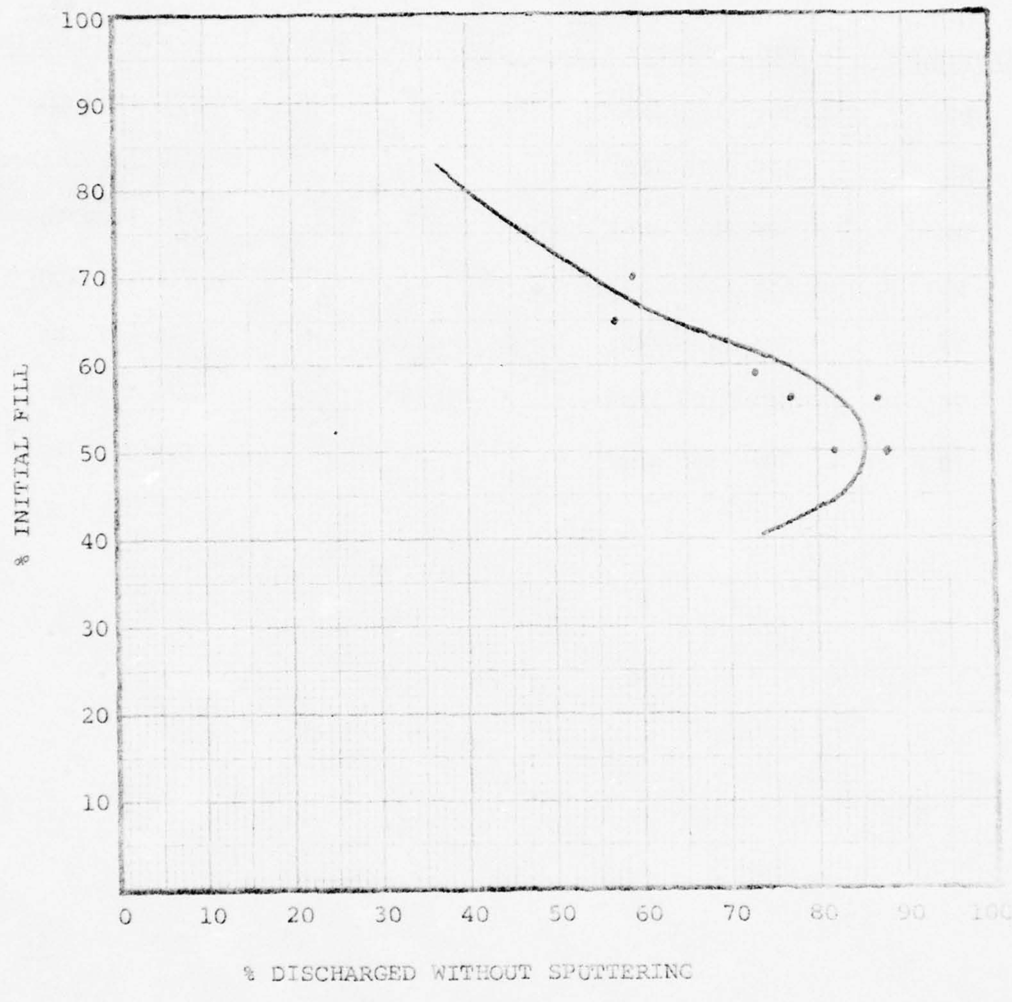


FIG. 11 PER CENT DISCHARGED WITHOUT SPUTTERING VERSUS FILL RATIO

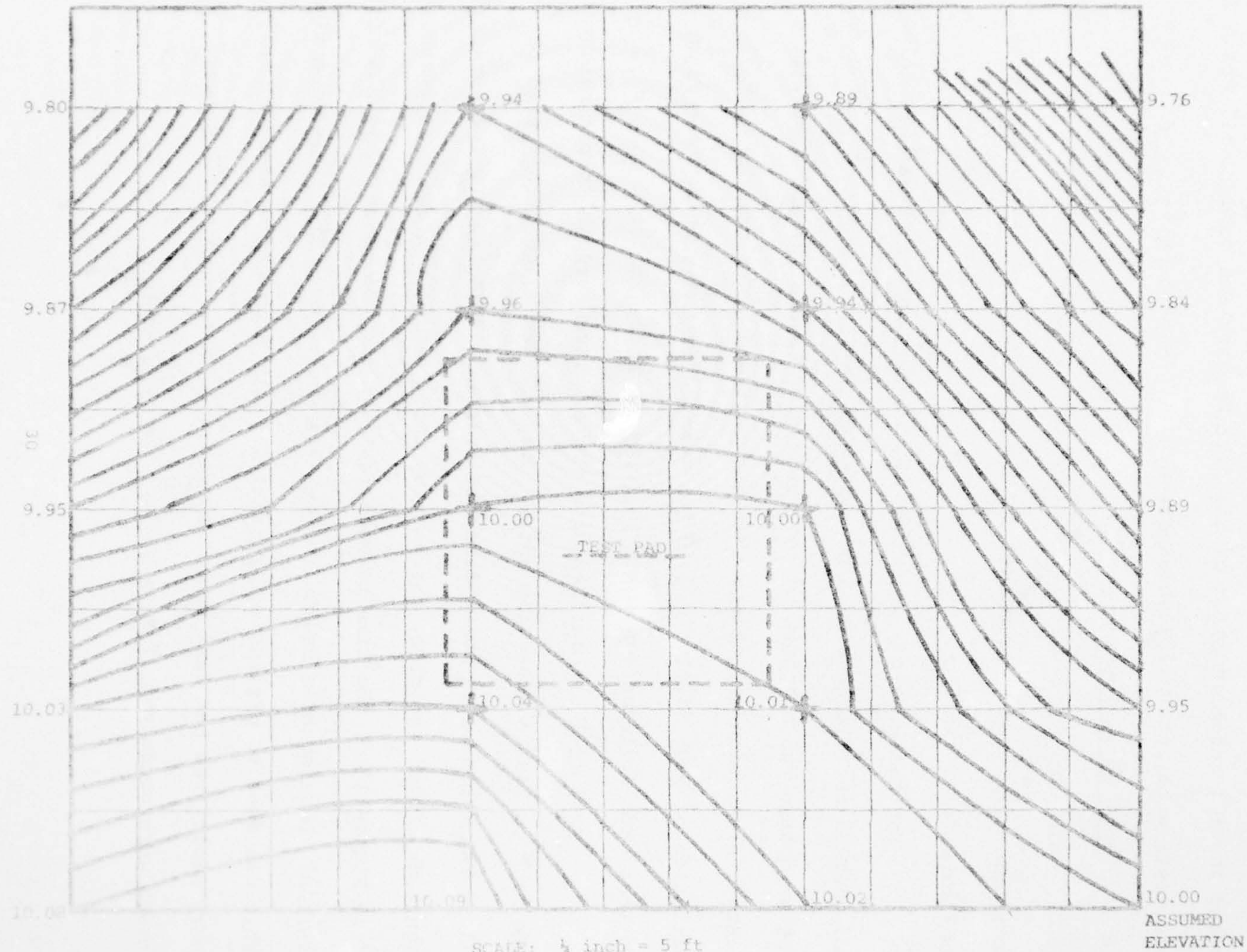
50-55% were the highest and that they dropped off as fill density was increased. Since it is impractical to convert the CB-10 with Halon 1211 levels below 50%, no tests were run. At this point, it was decided to accept the ICI recommendation of 55% fill density and conduct all Phase II fire tests with internally pressurized units at this level.

4.8 Fuel Spill Tests

The objective of this test series was to determine the area of fire that would result from fuel spills as a function of the amount of fuel spilled.

For these tests, a section of unused concrete runway was selected and checked for flatness by a professional surveying team. A plot of elevation change was prepared by the surveyors (Figure 12) and a smaller (48x48 ft) section was chosen that was flat and had a maximum elevation variation of 0.08 feet. A grid was painted on the surface (see Figure 13) so that each division contained four square feet (2x2 ft).

JP-4 fuel was spilled onto the concrete surface from a height of one foot or less. After the spill, the fuel was allowed to spread for 15, 30 or 120 seconds, at which time the area was estimated and the fuel was ignited. After ignition, the burning surface area was again estimated (see Figure 14). The time between ignition and the point where 90% of the initial burning area had burned out was observed as the extinction time. This was done to prevent unrealistically long extinction times if only a very small area had fuel remaining because it was originally deeper. No tests were conducted if wind gusts exceeded 3 mph.



SCALE: ¼ inch = 5 ft

FIG. 12 TOPOGRAPHIC PLAN OF CONCRETE SURFACE

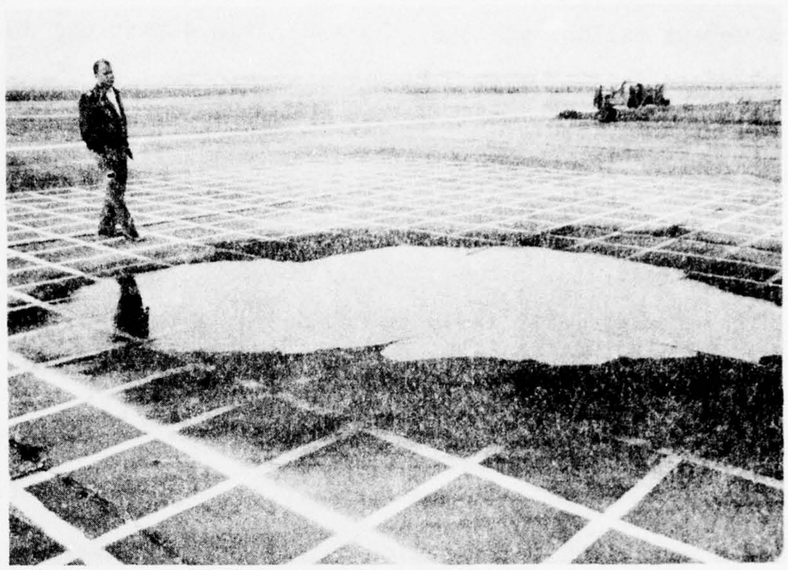


FIG. 13 FUEL SPILL ON GRID BEFORE IGNITION

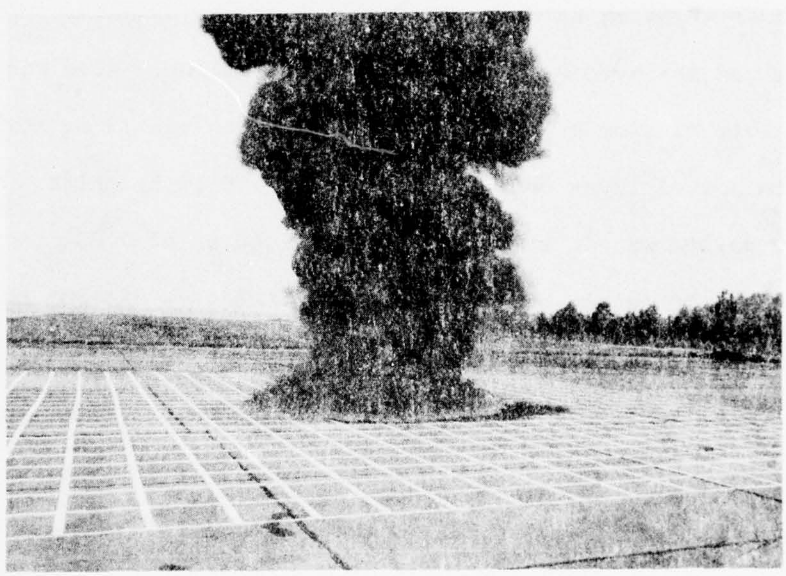


FIG. 14 FUEL SPILL ON GRID AFTER IGNITION

Test results are shown on Table VI. Figure 15 shows burning surface area versus gallons spilled. It was noticed that the surface area increased rapidly upon ignition and then remained almost constant until the fuel was consumed. Flame heights were difficult to estimate on larger fires.

4.8.1 Discussion

The area of fire likely to occur from a fuel spill is a function of the number of gallons spilled and the time allowed for the fuel to spread. It was also found that the number of square feet covered per gallon decreases considerably as the quantity of fuel spilled increases. For example, the area covered per gallon before ignition averaged 31 sq ft when only one gallon was spilled. When 20 gallons were spilled, one gallon covered an average of 15 sq ft. Likewise, after ignition, one gallon averaged about 41 sq ft when only one gallon was spilled. When 20 gallons were spilled the average was about 21 sq ft/gallon. (See Figures 16 and 17)

The minimum area covered by one gallon was 13 sq ft, which corresponds to a fuel layer 0.123 inches (about 1/8 inch) thick. The maximum area per gallon was 48 sq ft or a film thickness of 0.033 inches (about 1/32 inch). It seemed odd that thicker fuel layers did not burn longer than thinner films, and yet burn times were generally longer when the fuel had less time to spread out. For this to happen, the fuel must have been consumed at different rates, hence different fire intensities. To study this phenomenon further was beyond the scope of this program.

4.9 Phase I Conclusions

The nozzle submitted by The Ansul Company with a 0.422 inch

TABLE VI

FUEL SPILL AREAS

FUEL (GAL)	15 SECOND DELAY				30 SECOND DELAY				120 SECOND DELAY			
	BEFORE IGNITION (FT^2)	AFTER IGNITION (FT^2)	FLAME HEIGHT (FT)	FUEL CONSUMED (SEC)	BEFORE IGNITION (FT^2)	AFTER IGNITION (FT^2)	FLAME HEIGHT (FT)	FUEL CONSUMED (SEC)	BEFORE IGNITION (FT^2)	AFTER IGNITION (FT^2)	FLAME HEIGHT (FT)	FUEL CONSUMED (SEC)
1	24	40	6	90	32	40	6	90	36	44	6	60
2½	48	88	20	120	84	112	24	105	88	120	24	60
5	140	160	24	60	140	160	24	60	160	160	24	42
10	152	210	35	70	168	200	35	60	200	200	35	60
20	260	320	>40	95	288	430	>40	85	350	520	>40	60
50	-	-	-	-	-	-	-	-	700	1000 to 1200	>40	75

NOTE: Fuel consumed time is when 90% of fire area was out. Ambient temperatures ranged from 68°F - 72°F.

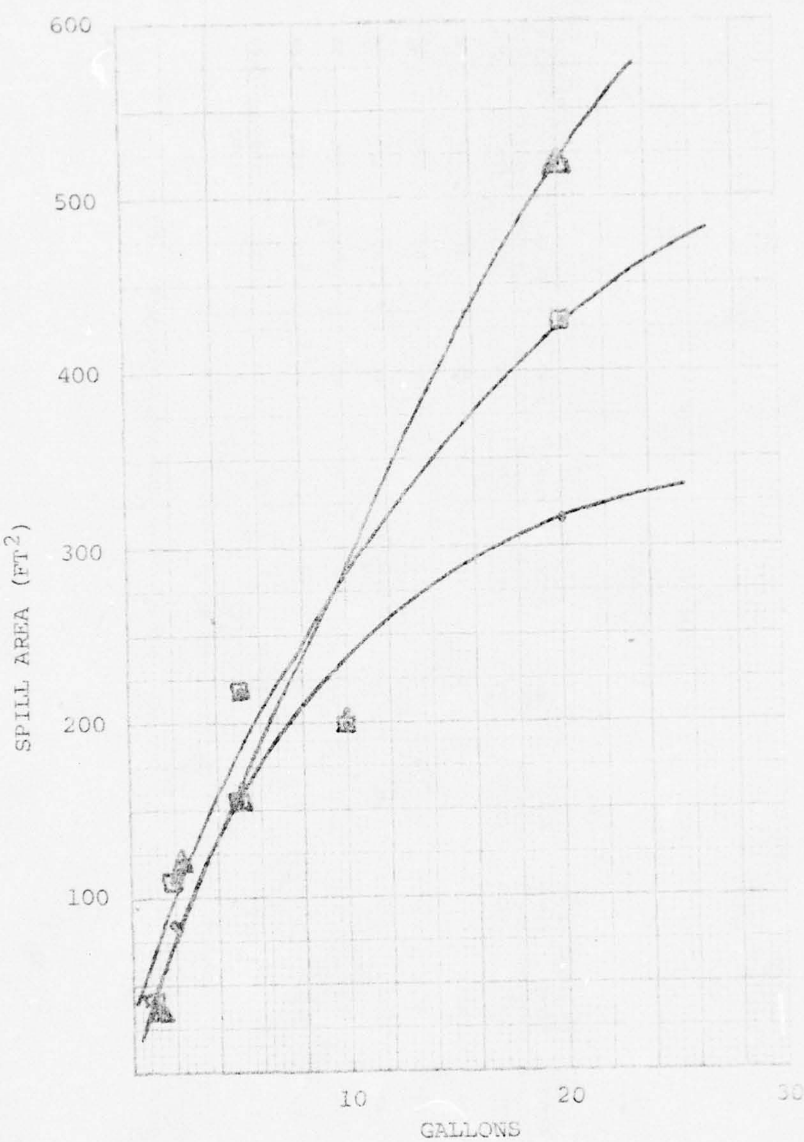


FIG. 15 FUEL SPILL AREAS VS AMOUNT OF FUEL SPILLED AFTER IGNITION

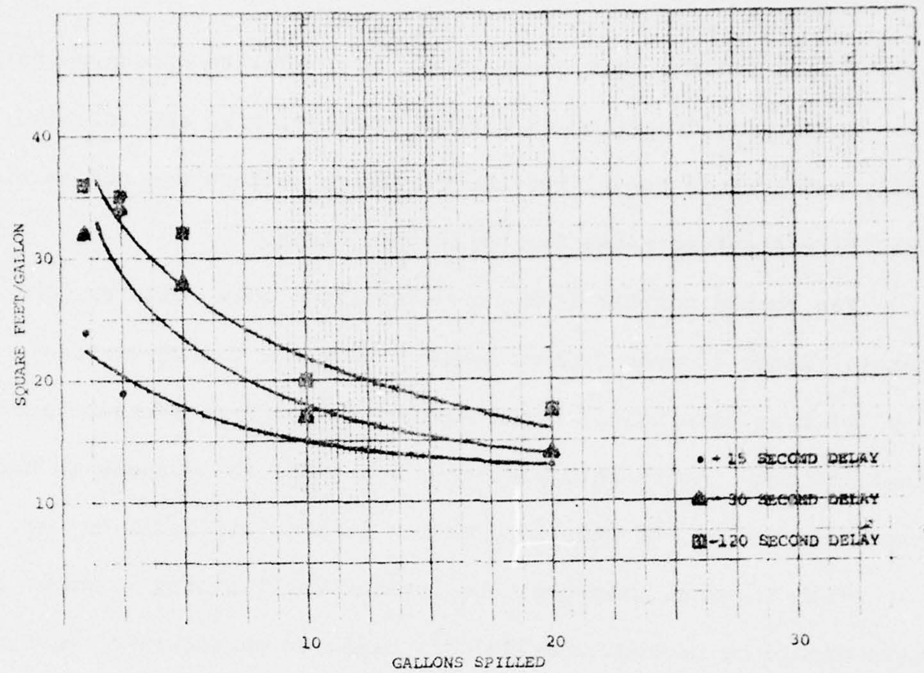


FIG. 16 AREA/GALLONS BEFORE IGNITION

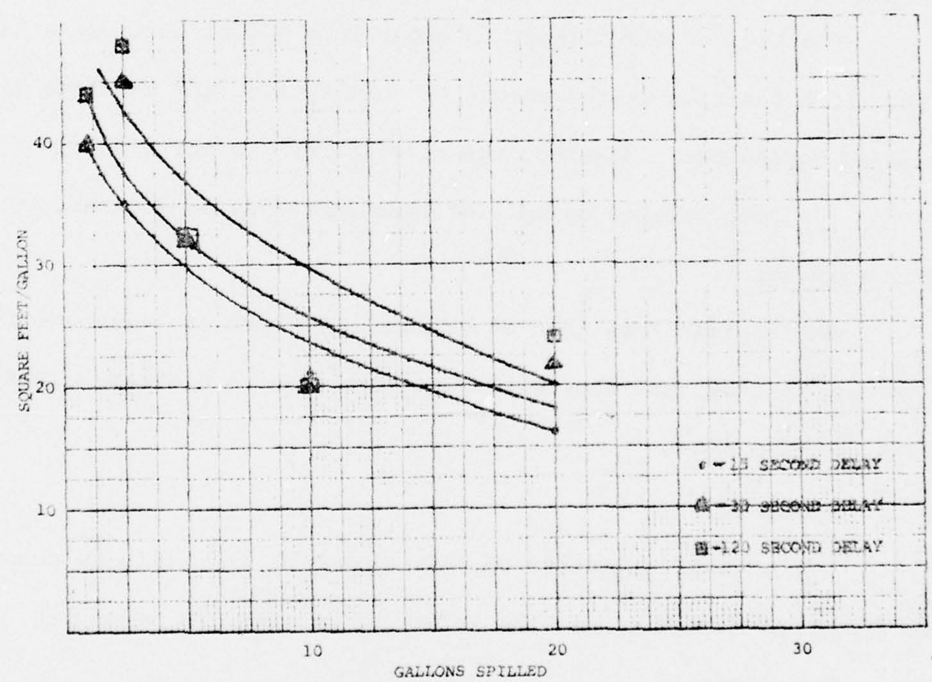


FIG. 17 AREA/GALLONS AFTER IGNITION

diameter throat had the most consistently high quality discharge pattern.

Converging-diverging or conical nozzles, like the ICI Plastic, generally had greater range, but the discharge pattern was not as wide at a normal fire fighting range for spill type fires.

Fan shaped nozzles lack range and often have voids or gaps in the discharge. Range is even further reduced when the fan is vertical.

With an external nitrogen source, the optimum pressure seemed to be about 150 psi. Above this pressure, there was an increase in nozzle reaction reported by the operator, making it more difficult to use.

With internal pressure, the optimum fill density is about 50-55%. Pressure should be between 200-240 psi, based on extinguisher equipment constraints.

The area of fire likely to occur from a fuel spill on a hard flat surface is a function of the amount of fuel spilled and the time allowed for it to spread out. However, the relationship is not linear.

The area covered by spilled fuel increases considerably when it starts burning.

Fuel spills less than 20 gallons will burn at least one minute, but it is unlikely that they will burn more than 1½ minutes unless additional fuel is added.

5.0 PHASE II

The overall objective of this phase was to verify by means of live fires and climatic test the selection of nozzles, pressures, etc, chosen after Phase I.

5.1 Extinguisher Configurations/Nozzles

Three different hardware configurations were suggested by companies involved in fire protection equipment or agents. Ansul evaluated both a stored (internal) and externally (regulated) pressurized unit and found the latter to be more effective[2]. ICI evaluated only stored pressure units and suggested a modification whereby the units could be filled volumetrically[3]. Stop Fire suggested another internally pressurized system with a different filling device and nozzle.

It should be noted that three different types of CB-10 units are in use at the present time. Units were manufactured originally by Fire Guard, Stop Fire and Fyr-Fyter. For the purpose of this program, the only significant difference between these units is the volume of the agent tank which varied up to 0.57 cubic feet. The Ansul modifications were set up on a Fire Guard unit. The ICI and Stop Fire modifications were set up on Stop Fire units. The Fyr-Fyter unit was not utilized during this phase since it had a larger fill port not compatible with existing modification kits.

5.1.1 The Ansul Modification

In this configuration, the extinguisher tank is charged only with agent prior to operation; the only pressure is the vapor pressure of the agent. Nitrogen is stored in a small, high pressure cylinder (1600 psi) attached by a bracket to the extinguisher frame and connected to the agent tank through a preset regulator (see Figure 18). The nitrogen cylinder volume is not critical as long as it contains sufficient gas to maintain constant pressure on the agent tank throughout the discharge. At the time

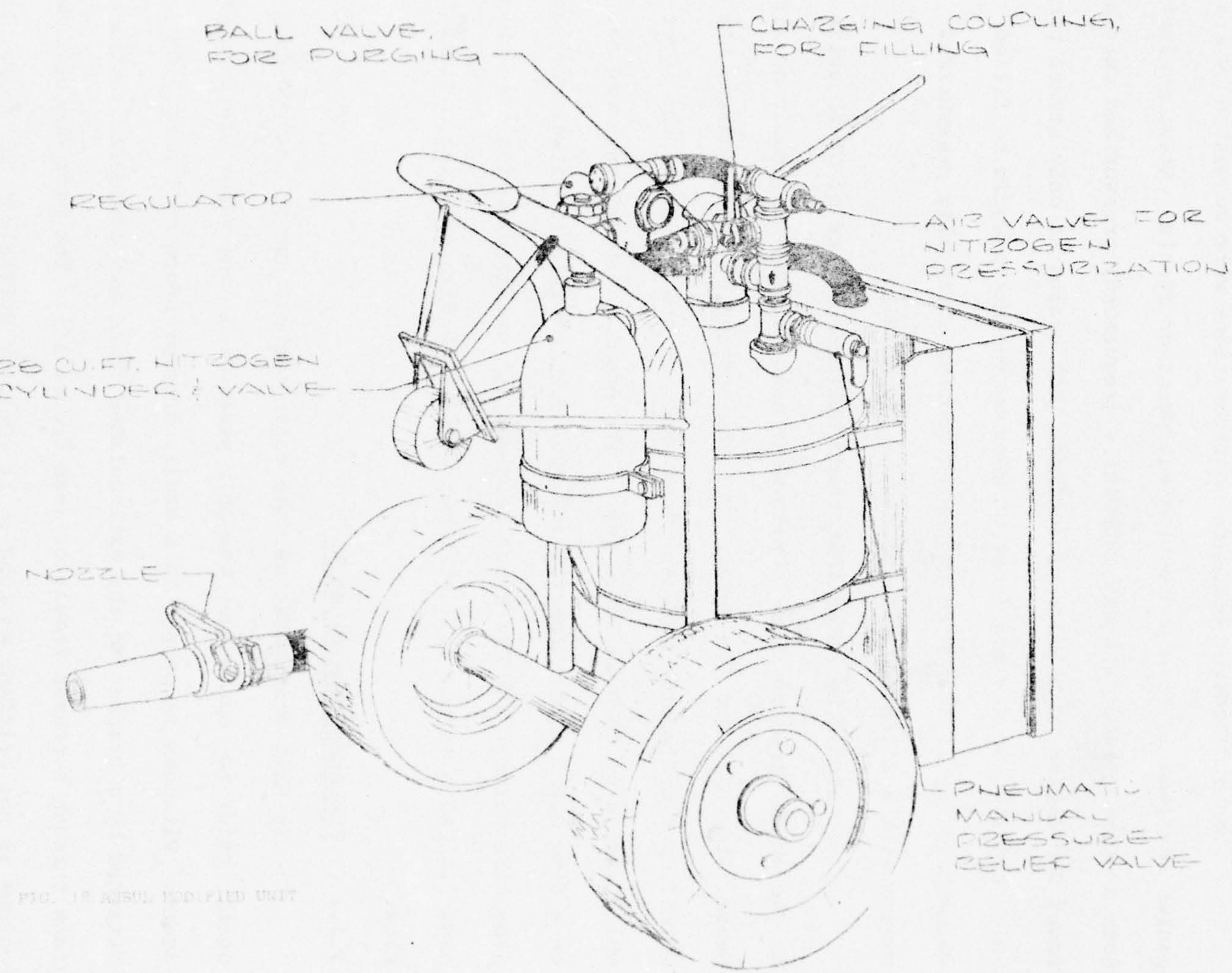


FIG. 19 MISOL MODIFIED UNIT

of operation, the valve on the nitrogen cylinder is opened, pressurizing the agent tank to expel the agent. The Ansul externally pressurized modification consisted of the following:

1. Modification of the operating valve mounted atop the tank.
2. A pressure relief valve preset to relieve at 267 to 295 psig. The pressure relief valve has a handle which can be used to manually bleed off tank pressure.
3. A quick-connect pressure coupling for charging the tank with Halon 1211.
4. A 28 cubic foot nitrogen cylinder and valve.
5. Brackets to secure the nitrogen cylinder to the frame.
6. A pressure regulator to control the flow of nitrogen when the system is activated.
7. A ball valve for purging the hose.
8. The necessary lines and fittings to plumb the nitrogen cylinder and regulator to the agent tank.

5.1.2 The ICI Modification

ICI suggested a stored or internally pressurized configuration, operating the same as existing CB units. Mechanical changes were as follows:

1. The existing pressure gauge was removed and in its place a brass "T" adaptor was connected. One side of the "T" had a quick-connect to attach the Halon 1211 filling hose. The gauge was then replaced in the other side of the "T" (see Figure 19).

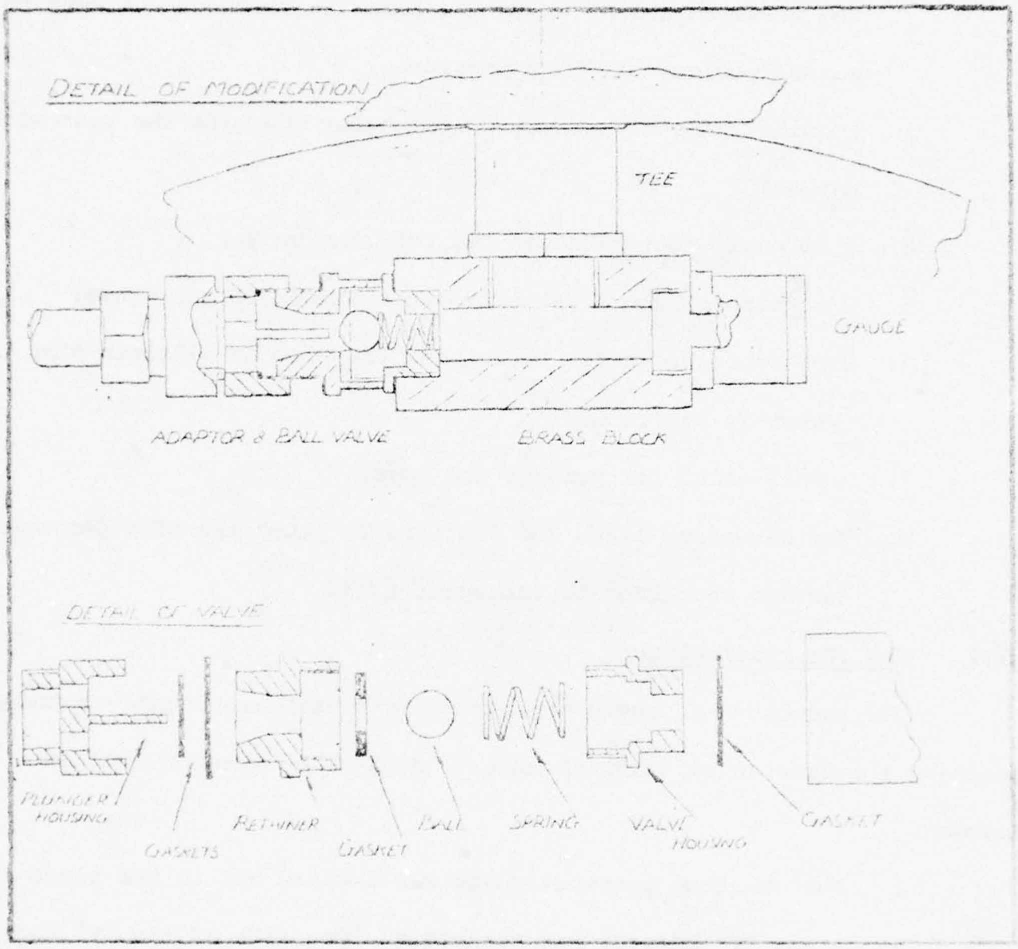


FIG. 19 ICI FILLING ADAPTOR

2. The existing filling cap was (without disturbing the pressure relief disc or the Schrader valve) modified to accommodate two small copper dip tubes so the unit could be filled volumetrically (Figure 20). Both dip tubes had threaded caps that were opened during filling. One tube was one inch longer than the other. As agent was added to the tank and reached the longer tube, liquid would spurt out a small hole in the cap. At this point, the operator would close this cap. When liquid reached the shorter tube, the unit would be full. By opening the cap on the longer tube, the unit could be checked for agent fill at periodic inspection intervals.

5.1.3 The Stop Fire Modification

Stop Fire suggested a replacement filling cap that contained a Schrader valve, a bleed valve, a pressure relief disc and a quick-connect to attach to the Halon 1211 filling hose (Figure 21).

During the filling operation, the bleed valve would be partially opened to vent the tank as agent entered. When filled with the correct weight, the tank would be pressurized with nitrogen through the Schrader valve. With this conversion, the unit must be put on a large scale during filling.

5.1.4 Nozzles

Based on the results of Phase I, the Ansul 0.422 inch and the ICI Plastic nozzles were chosen for extensive evaluation during Phase II. These nozzles are shown schematically in Figures 22 and 23.

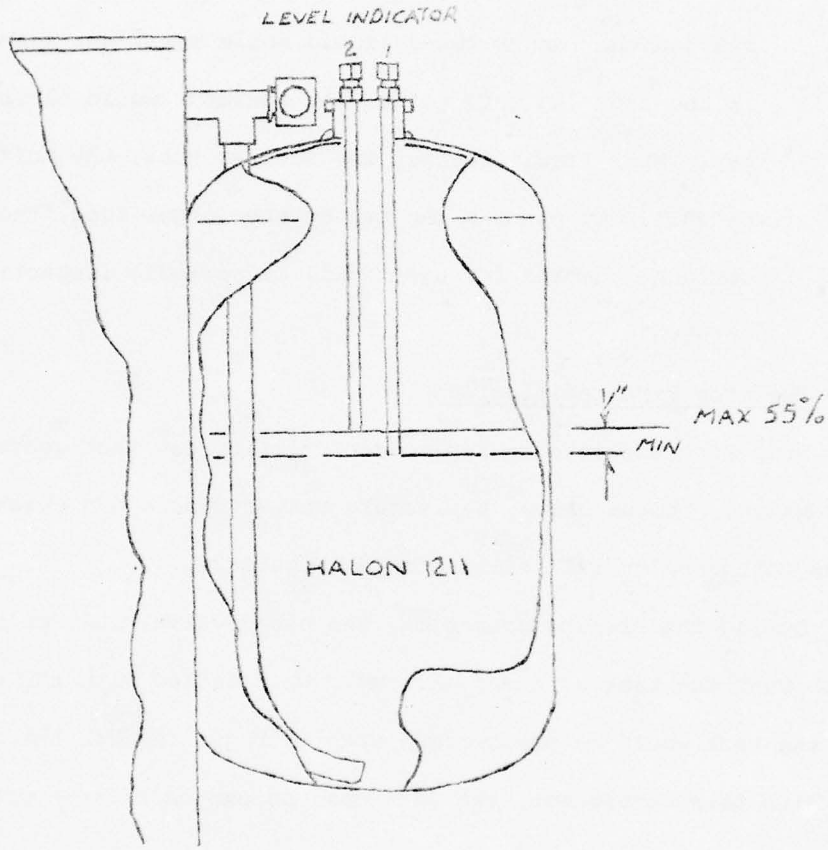
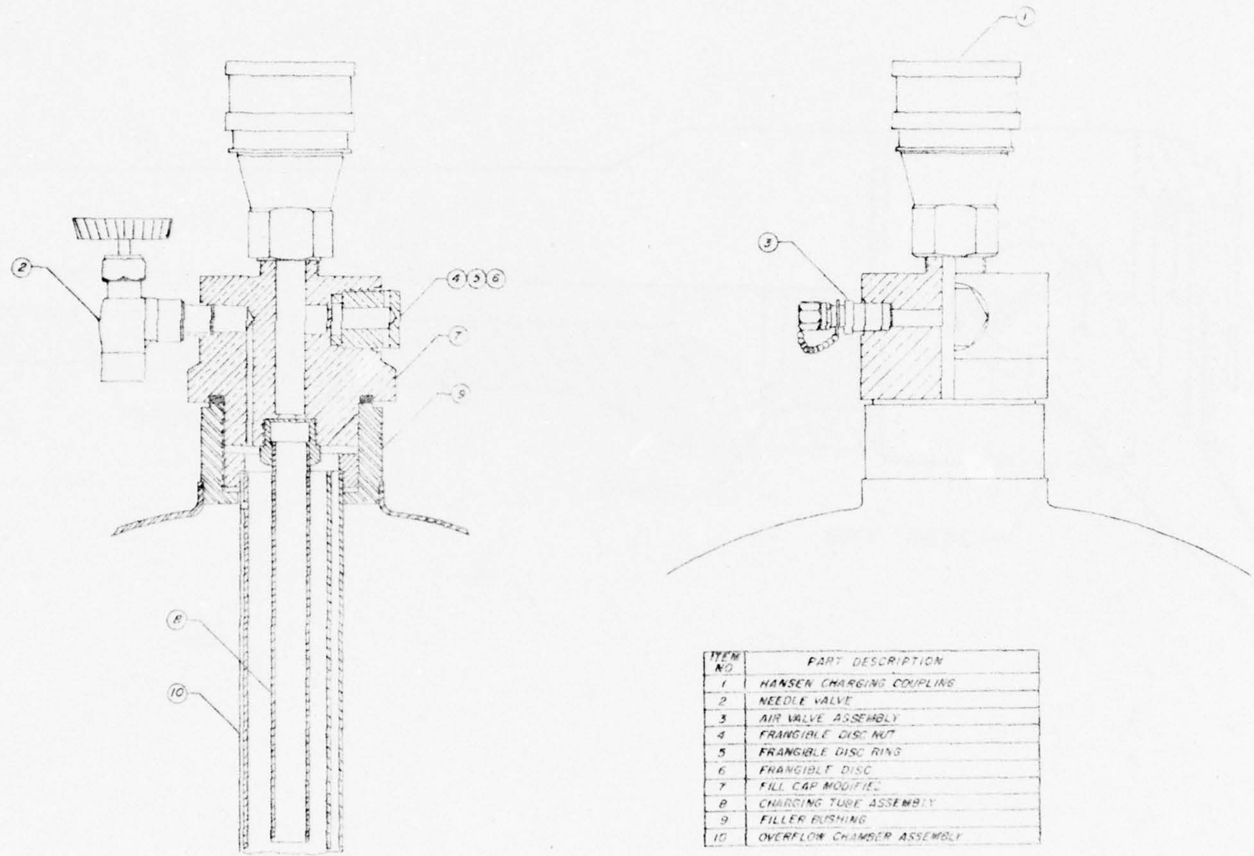


FIG. 20 ICI FILLING INDICATORS



ITEM NO	PART DESCRIPTION
1	HANSEN CHARGING COUPLING
2	NEEDLE VALVE
3	AIR VALVE ASSEMBLY
4	FRANGIBLE DISC NUT
5	FRANGIBLE DISC RING
6	FRANGIBLT DISC
7	FILL CAP MODIFIED
8	CHARGING TUBE ASSEMBLY
9	FILLER BUSHING
10	OVERFLOW CHAMBER ASSEMBLY

FIG. 21 STOP FIRE MODIFICATION

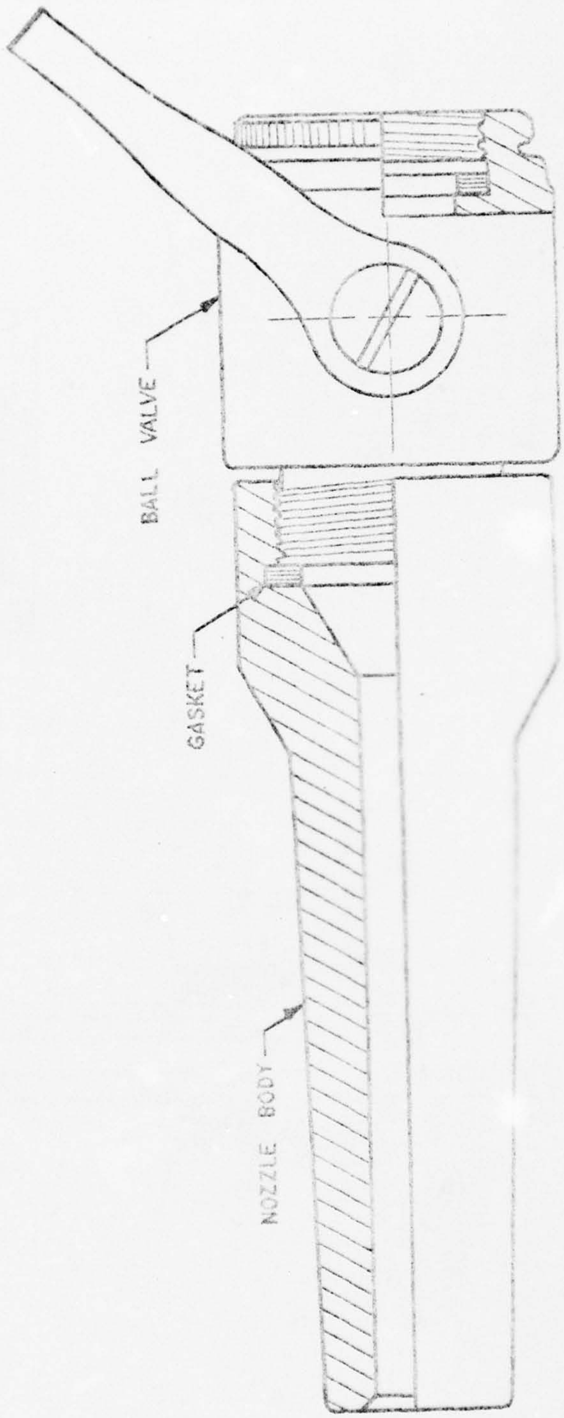


FIG. 22 ANNUL (0.422) NOZZLE

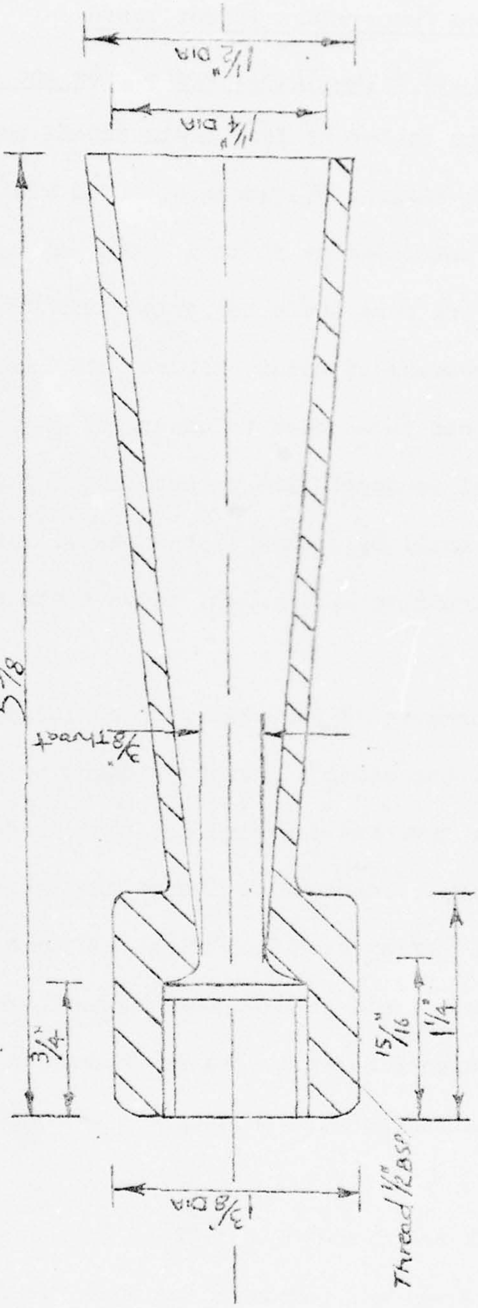


FIG. 23 ICI NOZZLE

5.2 Live Fire and Temperature Effect Tests

5.2.1 Simulated Spill Fires (Pool) Procedures and Conditions

Since a large number of fire tests cannot be conducted on a concrete surface without ruining the surface, a pad was constructed to hold water on which the fuel could be floated. The pad was sloped toward the center so that the fire area could be varied from 15 to 50 feet in diameter by the addition or removal of water (Figure 24). Since a sufficient quantity of fuel (JP-4) had to be used to ensure at least a 2½ minute burn, the result was a fuel in-depth fire rather than a thin film fire that would result from a spill on a hard flat surface. Since fuel in-depth fires are more difficult to extinguish, these tests represented "worst case" conditions.

Three radiometers (Figure 24) were positioned as recommended by R. Alger[5] to measure the radiant energy produced by the fire. During each test, the radiometer operator signaled the test conductor when the fire reached peak intensity. The test conductor then signaled the fire fighter to begin extinction. After each test fire, all unconsumed fuel was burned off so that fresh fuel could be used for the next test.

The extinguisher being tested was placed on a scale and the amount of Halon 1211 discharged was recorded every five seconds until the test was concluded.

During each test, the fire fighter approached the fire from the upwind direction and was not permitted to move laterally more than ± 30 degrees. In addition, the fire fighter was not permitted to walk into the fuel. Tests were not conducted when wind gusts exceeded 3 mph, and the

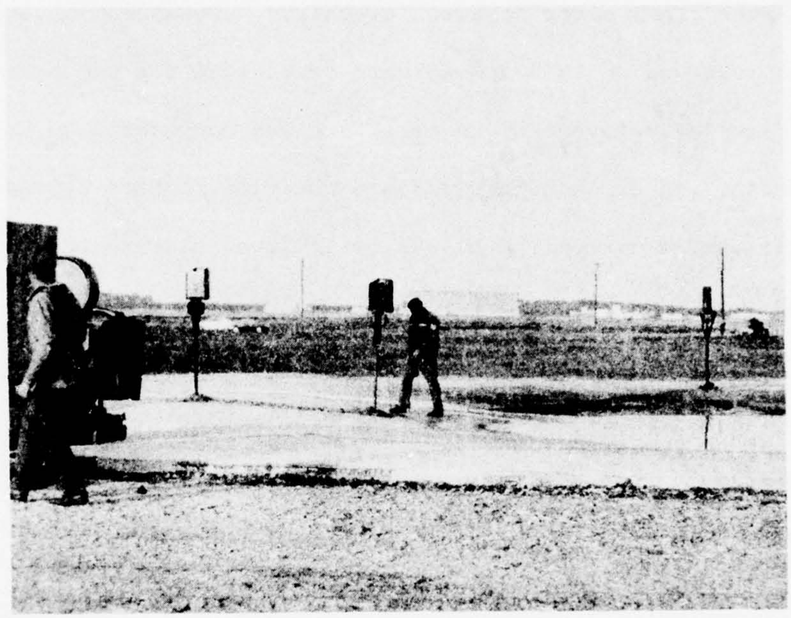


FIG. 24 TEST PIT AND RADIOMETERS

majority were completed with the wind between 0 and 1 mph, which is considered one of the most difficult fires to extinguish. Figure 25 shows a typical fire condition.

5.2.2 Tire Fires Procedures and Conditions

These tests were conducted on two aircraft wheel and tire assemblies mounted above a pan of JP-4 and/or gasoline (Figure 26). Tires were not pressurized as a safety precaution. Tires so mounted were given varying preburn times prior to agent discharge. Potassium bicarbonate based dry chemical, Halon 1211 and CB were discharged for comparison of fire suppression effectiveness. A tire fire was considered to be extinguished when reignition did not take place. The fire fighter approached the fire from the upwind direction but was not allowed closer than 15 feet to the burning tire.

5.2.3 Aircraft Engine/Running Fuel Fires Procedures and Conditions

A salvaged T-33 aircraft, including engine and all components, was mounted on concrete pillars for this series of tests (Figure 27). A 55-gallon drum mounted on an elevated platform was piped to allow fuel to flow by gravity up to a rate of seven gallons per minute. Near the aircraft, the flow was split into two pipes that emptied into pans (24"x12"x8") placed in front of and behind the engine. When the pans overflowed, the fuel ran along the inside skin and then flowed out holes and cracks onto the ground, causing a three dimensional fire. With this configuration, agent injected into the air intake had to flow 9 feet to the front of the engine and the first pan fire, and another 10 feet through and around the engine to the second pan fire in the tail pipe section.

FIG. 25 TYPICAL TEST FIRE

FIG. 26 TYPICAL TIRE FIRE

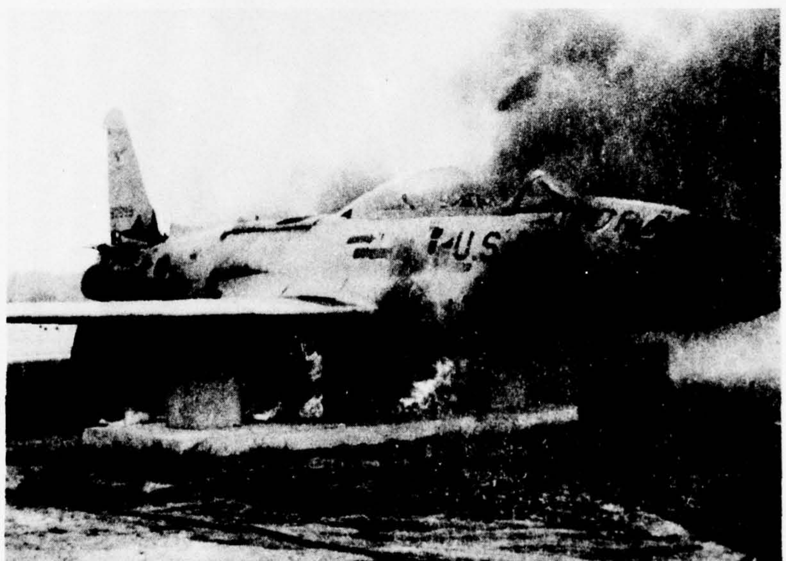


FIG. 27 T-33 TEST AIRCRAFT

During these tests, the fire fighter was permitted to inject agent into only one of the two air intakes and at times the tail pipe. After extinguishment of the internal fire, the operator attacked the running fuel and ground fire. A 30 or 60 second preburn was allowed before the agent was discharged.

5.2.4 Spill Fires (Concrete) Procedures and Conditions

The test apparatus described in paragraph 4.8 was utilized for these tests (Figure 28). A report by the US Army[4] shows that 73% of fuel spills within the Air Force are four gallons or less. An additional 23% are 5-42 gallons with 4% above 42 gallons. Since the CB-10 extinguisher is a first aid appliance, it should be at least capable of extinguishing a high percentage of fuel spill fires likely to occur on the flight line. It should be remembered these units will be voluntarily operated by non-fire fighters and without the benefit of protective clothing.

The fire fighter was restricted to approaching from an upwind position and not allowed to walk into the fuel. Fires were allowed a preburn of 15 seconds, since results of Phase I indicated a full conflagration would last only about 60 seconds for fires of this type. Fuel was allowed to free flow for two minutes before ignition. Fires were not conducted when wind gusts exceeded 8 mph.

5.2.5 Novice Trials Procedures and Conditions

At the conclusion of live fire tests by an experienced operator, flight line personnel (crew chiefs and mechanics) were randomly selected to further evaluate the chosen extinguisher configurations. These individuals had little or no fire fighting experience. Since modified extinguishers

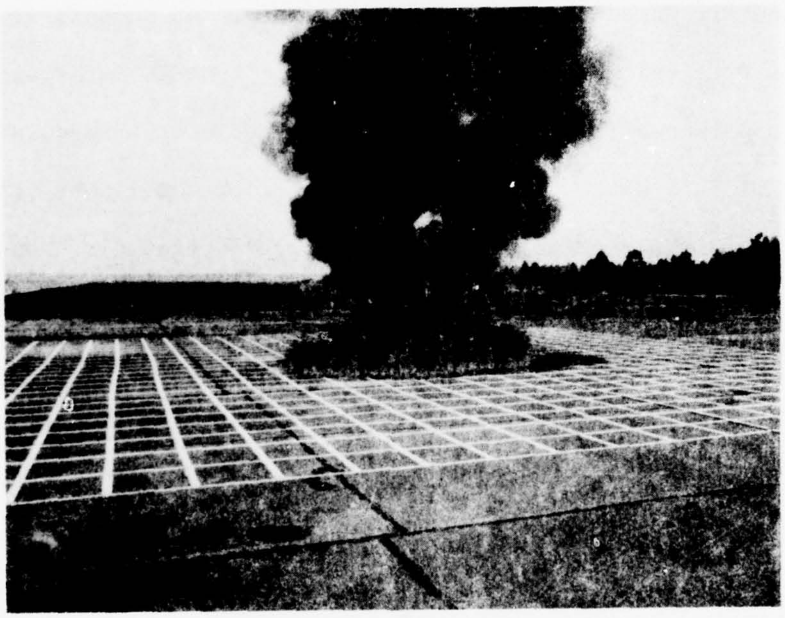


FIG. 28 TYPICAL SPILL FIRE

did not have a printed instruction plate (label), verbal instructions were given on how to charge the unit and activate the nozzle for all fire situations. With one exception, no application instructions were given for pool type fires. On aircraft fires, novices were instructed to discharge agent in one air intake only until they felt the internal fire was extinguished. They would then proceed to attack the running fuel and ground fire. With tire fires, the extinguisher was positioned so as to keep the novice at least ten feet from the fire. None of the novices were issued protective clothing.

5.2.6 Temperature Effect Tests Procedures and Conditions:

Both extinguisher configurations (internal and external) were tested for operation at temperatures simulating arctic and tropic conditions (-60°F and +140°F). In addition, one CB extinguisher was compared to Halon 1211 at test temperatures. Units were allowed to remain at test temperatures for 24 hours to assure stabilization prior to operation. Cameras located in test chamber provided photographic documentation of nozzle reaction, pattern width and length of discharge. Length of discharge and pattern width were measured through use of test apparatus described in paragraph 4.2.1. Time of discharge was recorded manually by the use of a stopwatch.

Since the purpose of this test series was to determine the temperature at which malfunctions might occur within the range of -60°F to 140°F, the initial tests were conducted at these extremes. Should a discharge be unsatisfactory at the extremes, additional tests would be run to determine operating temperature limits.

5.3 Results of Live Fire and Temperature Effect Tests:

5.3.1 Spill Fires (Pool)

Table VII shows the results of live fire tests conducted with the extinguisher configurations and nozzles selected after Phase I. It should be noted that three tests on Table VII were conducted with internally pressurized units that were not recharged after a previous test. The most dramatic was the Ansul internal modification and 0.422 nozzle where a 200 sq ft fire was easily extinguished, fresh fuel added twice, and the fire extinguished both times. This was intended to simulate reflash conditions with a continuous fuel supply. Likewise, the externally pressurized unit extinguished a 450 sq ft fire after extinguishing a 356 sq ft fire. Figure 29 shows a typical large fire being attacked with an externally pressurized unit.

5.3.2 CB Comparisons

Unmodified CB-10 extinguishers using CB as the agent were tested on pool fires to serve as a basis for comparing modified units with Halon 1211. The results are shown on Table VIII.

5.3.3 Tire Fires

Table IX shows the results of tire fire tests conducted with converted CB-10 units as well as comparison tests conducted with potassium bicarbonate based dry chemical and CB. For these fires, the 350 dry chemical unit on the US Air Force P-13 ramp patrol fire truck was used.

5.3.4 Aircraft Engine/Running Fuel Fires

The following is a brief description, including results, of engine and running fuel fires conducted on the salvaged T-33 aircraft:

TABLE VII

RESULTS OF SPILL FIRES (POOL)

CONFIGURATION	NOZZLE	PRESSURE (psig)	FIRE SIZE (FT^2)	EXTINGUISH-MENT TIME	COMMENTS
ICI (INTERNAL)	ICI PLASTIC	200	215	5.5	GOOD TECHNIQUE
ICI (INTERNAL)	ICI PLASTIC	145	242	NE	NOT RECHARGED AFTER ABOVE TEST; POOR OPERATOR TECHNIQUE
STOP FIRE (INTERNAL)	ICI PLASTIC	200	380	NE	POOR TECHNIQUE
ANSUL (INTERNAL)	ROCKWOOD	200	200	NE	LOW FLOW RATE; NOZZLE NOT EVALUATED FURTHER
ICI (INTERNAL)	STOP FIRE #1 FAN	200	250	NE	LOW FLOW RATE; NOZZLE NOT EVALUATED FURTHER
STOP FIRE (INTERNAL)	ICI PLASTIC	200	210	NE	ALMOST OUT 11 SEC; POOR TECHNIQUE
ANSUL (INTERNAL)	ANSUL 0.422	200	200	6.0	GOOD TECHNIQUE
ANSUL (INTERNAL)	ANSUL 0.422	150	190	8.0	EXTINGUISHER NOT RE-CHARGED AFTER ABOVE TEST
ANSUL (INTERNAL)	ANSUL 0.422	120	190	6.0	EXTINGUISHER NOT RE-CHARGED AFTER ABOVE TEST

TABLE VII (CONT'D)

CONFIGURATION	NOZZLE	PRESSURE (psig)	FIRE SIZE (FT^2)	EXTINGUISHMENT TIME	COMMENTS
ICI (INTERNAL)	ANSUL 0.422	200	280	17 SEC	GOOD TECHNIQUE
STOP FIRE (INTERNAL)	ANSUL 0.422	200	290	16 SEC	GOOD TECHNIQUE
ANSUL (EXTERNAL)	ANSUL 0.422	185	356	7 SEC	GOOD TECHNIQUE
ANSUL (EXTERNAL)	ANSUL 0.422	185	450	10 SEC	EXTINGUISHER NOT RE-CHARGED AFTER ABOVE TEST
ANSUL (EXTERNAL)	ANSUL 0.422	185	525	21 SEC	ALMOST OUT AT 13 SECONDS
ANSUL (EXTERNAL)	ANSUL 0.422	140	700	9 SEC	LESS NOZZLE REACTION COM-PARED TO ABOVE TEST
ANSUL (EXTERNAL)	ANSUL 0.422	150	1180	19 SEC	GOOD TECHNIQUE
ANSUL (EXTERNAL)	ANSUL 0.422	150	1250	NE	ALMOST EXTINGUISHED
ANSUL (EXTERNAL)	ANSUL 0.422	160	950	NE	ALMOST EXTINGUISHED

TABLE VIII

CB SPILL FIRES (POOL)

CONFIGURATION	NOZZLE POSITION	PRESSURE (psig)	FIRE SIZE (FT^2)	EXTINGUISH-MENT TIME	COMMENTS
FIRE-GUARD (INTERNAL	ST STREAM	200	190	11.0	GOOD TECHNIQUE
STOP FIRE (INTERNAL)	ST STREAM	200	300	NE	NOZZLE MALFUNCTION
STOP FIRE (INTERNAL)	ST STREAM	200	200	9	GOOD TECHNIQUE
FIRE-GUARD (INTERNAL)	ST STREAM	200	250	16	APPEARED TO NEAR LIMIT OF EXTINGUISHER CAPABILITY

TABLE IX

TIRE FIRE TEST RESULTS

AGENT	EXTINGUISHER	NOZZLE	PREBURN (MIN)	EXTINGUISH-MENT TIME (SEC)	REFLASH TIME (MIN)	FUEL CONSUMED	COMMENTS
1211	ANSUL (INTERNAL)	ANSUL 0.422	2.0	4.2	NO	NO	EXTINGUISHED
1211	STOP FIRE (INTERNAL	ICI PLASTIC	2.0	4.2	NO	NO	EXTINGUISHED
DRY CHEMICAL	P-13 VEHICLE	P-13	2.0	-	-	NO	NOT EXTINGUISHED
CB	STOP FIRE (INTERNAL)	CB	4.0	5.0	NO	NO	EXTINGUISHED
1211	P-13 VEHICLE	P-13	8.5	6.0	NO	NO	EXTINGUISHED; MAGNESIUM MELTED AND FLOWED INTO FUEL PAN
DRY CHEMICAL	P-13 VEHICLE	P-13	8.5	-	-	NO	NOT EXTINGUISHED
1211	P-13 VEHICLE	P-13	15	7.0	18	YES	TIRE ALMOST CONSUMED PRIOR TO AGENT DISCHARGE
CB	STOP FIRE (INTERNAL)	CB	15	7.2	15	YES	TIRE ALMOST CONSUMED PRIOR TO AGENT DISCHARGE
DRY CHEMICAL	P-13 VEHICLE	P-13	15	7.0	15	YES	TIRE ALMOST CONSUMED PRIOR TO AGENT DISCHARGE

NOTE: A [illegible] VEHICLE AND ASSOCIATED EQUIPMENT UTILIZED FOR SOME TESTS AS INDICATED.

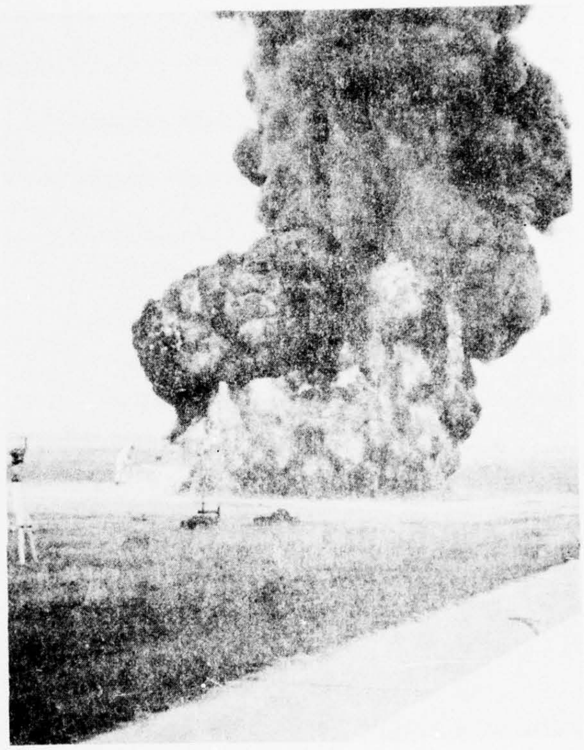


FIG. 29 TYPICAL LARGE SPILL FIRE

1. Aircraft Fire #1:

Configuration - Stop Fire Internal

Nozzle - ICI Plastic

Pressure - 200 psig

Fuel Flow Rate - 7 GPM

Fuel/Fire Location - Front of engine and flowed onto ground through aircraft skin

Agent discharged four seconds into one air intake extinguished all fire in the engine compartment. Fire fighter then extinguished ground fire in four seconds.

2. Aircraft Fire #2:

Configuration - ICI Internal

Nozzle - ICI Plastic

Pressure - 200 psig

Fuel Flow Rate - 7 GPM

Fuel/Fire Location - Behind engine and flowed onto ground through aircraft skin

Agent discharged 16 seconds into one intake extinguished all fire in engine compartment. Fire fighter then extinguished ground and running fuel fire with 14 second discharge. Ground fire was obstructed by concrete pillars supporting aircraft.

3. Aircraft Fire #3:

Configuration - Stop Fire Internal (Two Units Used)

Nozzle - (1) Ansul 0.422

(2) ICI Plastic

Pressure - 200 psig

Fuel Flow Rate - 7 GPM

Fuel/Fire Location - Front of engine and flowing onto ground

On the first attempt, the fire fighter extinguished all internal fire through air intake and all ground fire except for a filter saturated with fuel that fell out of the engine compartment behind a concrete pillar. The agent was exhausted before the filter could be extinguished. The fuel on the ground reignited, and the flames ignited the engine compartment fire. A second unit extinguished all fire. On the second attempt, the ground fire was extinguished before the engine compartment fire, as shown in Figure 30.

4. Aircraft Fire #4:

Configuration - ICI Internal

Nozzle - Ansul 0.422

Pressure - 200 psig

Fuel Flow Rate - 3 GPM

Fuel/Fire Location - Pan behind engine (tail pipe removed)

Agent discharged into one air intake for 15 seconds extinguished fire. No ground or running fuel fire.

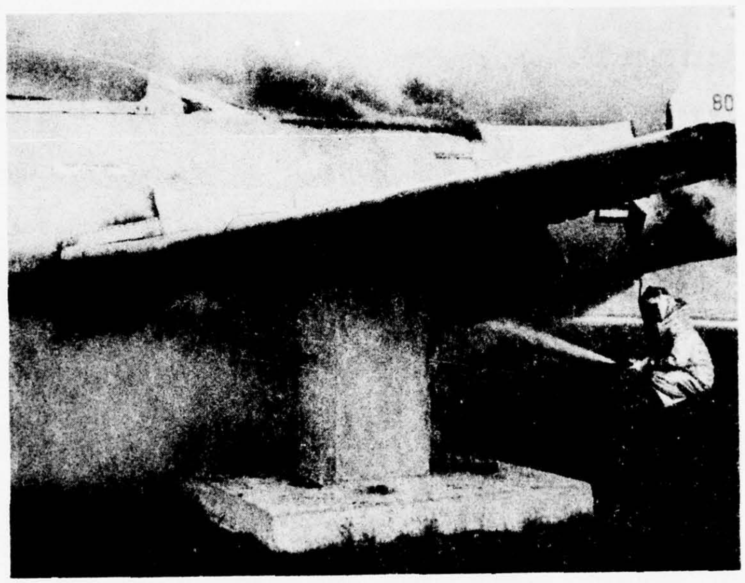


FIG. 30 AIRCRAFT ENGINE FIRE

5. <u>Aircraft Fire #5</u>:

Configuration - Stop Fire Internal

Nozzle - ICI Plastic

Pressure - 200 psig

Fuel Flow Rate - Zero - fuel in pan only

Fuel/Fire Location - Behind engine

Agent discharged into one air intake for 7 seconds extinguished all fire.

6. <u>Aircraft Fire #6</u>:

Configuration - ICI Internal

Nozzle - ICI Plastic

Pressure - 200 psig

Fuel Flow Rate - 7 GPM

Fuel/Fire Location - Front of engine and flowing onto ground

Both fires completely extinguished in 10 seconds.

7. <u>Aircraft Fire #7</u>:

Configuration - Ansul Internal

Nozzle - Ansul 0.422

Pressure - 200 psig

Fuel Flow Rate - 7 GPM

Fuel/Fire Location - Front and rear (3.5 GPM each)

Agent injected into air intake; then extensive ground and running fuel fire extinguished easily.

5.3.5 Spill Fires (Concrete)

Table X shows the results of live fire tests conducted on a level concrete pad. Facility utilized was described in paragraph 4.8. It should be noted that two tests on Table X were conducted with the same extinguisher without recharging after the previous test. Test fire #3 should have been extinguished. Operator moved in too close to the oblong shaped fire, allowing a reflash across the previously extinguished surface. Test fire #4 was judged to be beyond the capability of the internal pressurized configuration. The fire condition was altered when increased burning of the joint sealer was encountered during repeat fires, resulting in a more difficult extinguishment. A typical fire is shown in Figure 31.

5.3.6 Novice Trial Fires

Table XI shows the results of novice spill fires (pool). Figures 32 and 33 depict actual fire scenes. All participants attacked the fires without hesitation and reported a significant cooling effect upon agent discharge. Operator (test #4) assumed a crouched position, attributed to the heat from the fire. Operator (test #5) was uncertain as to whether he would attempt to extinguish a fire of that magnitude on the flightline due to the heat radiation.

Three aircraft and two tire fire tests were conducted as described in paragraph 5.2.5. All fires were easily extinguished by the novices. Figures 34 and 35 show actual fire suppression operations.

5.3.7 Temperature Effect Tests

Table XII shows the results of the tests conducted at $-60^{\circ}F$. One extinguisher (test #1) was discharged at the reduced pressure resulting

TABLE X

RESULTS OF SPILL FIRES (CONCRETE)

FIRE NO.	CONFIGURATION	NOZZLE	FUEL (GAL)	AREA (FT^2) BEFORE IGNITION	AREA (FT^2) AFTER IGNITION	WIND (MPH)	EXTINGUISH-MENT TIME (SEC)	COMMENTS
1	STOP FIRE (INTERNAL)	ANSUL 0.422	40	540	720	4-6	7.0	GOOD TECHNIQUE
2	STOP FIRE (INTERNAL)	ANSUL 0.422	40	520	740	4-6	7.5	EXTINGUISHER NOT RECHARGED AFTER ABOVE TEST
3	ICI (INTERNAL	ANSUL 0.422	52	750	1100	4-6	NE	ALMOST OUT 11 SEC; POOR TECHNIQUE
4	ANSUL (INTERNAL)	ANSUL 0.422	60	880	1340	0-1	NE	EXTINGUISHED 95% PRIOR TO RUNNING OUT OF AGENT

NOTE: AMBIENT TEMPERATURES RANGED FROM 65°F - 69°F.

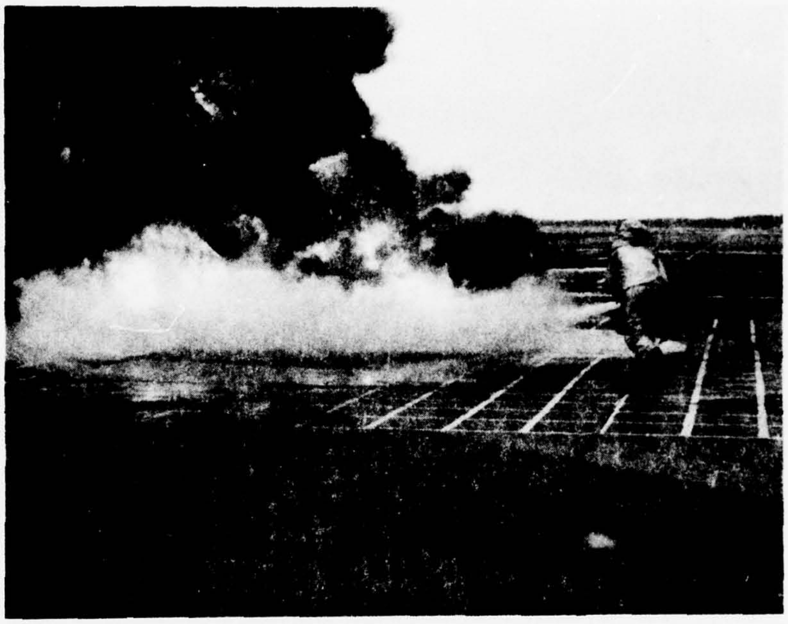


FIG. 31 SPILL FIRE SUPPRESSION

TABLE XI

RESULTS OF NOVICE SPILL FIRES (POOL)

FIRE NO.	CONFIGURATION	NOZZLE	PRESSURE (psig)	FIRE SIZE (FT^2)	EXTINGUISH-MENT TIME (SEC)	COMMENTS
1	ANSUL (INTERNAL)	0.422	200	200	NE	ALMOST OUT 9 SEC; OPERATOR RAISED NOZZLE TO EXTINGUISH FUEL VAPOR FIRE CAUSING REFLASH
2	STOP FIRE (INTERNAL)	0.422	200	200	17	ALMOST OUT 11 SEC; POOR TECHNIQUE
3	STOP FIRE (INTERNAL)	0.422	200	200	21	POOR TECHNIQUE; MOVED NOZZLE TOO FAST
4	ICI (INTERNAL)	0.422	200	200	NE	POOR TECHNIQUE; OPERATOR ASSUMED A CROUCHED POSI-TION WHILE ELEVATING THE NOZZLE
5	ANSUL (EXTERNAL)	0.422	150	800	NE	ALMOST OUT ON THREE OCCASIONS
6	ANSUL (EXTERNAL)	0.422	150	840	NE	ALMOST OUT 18 SEC; OPERATOR STARTED AND STOPPED DIS-CHARGE; POOR TECHNIQUE

FIG. 32 NOVICE POOL FIRE #2 (AREA 200 FT^2)

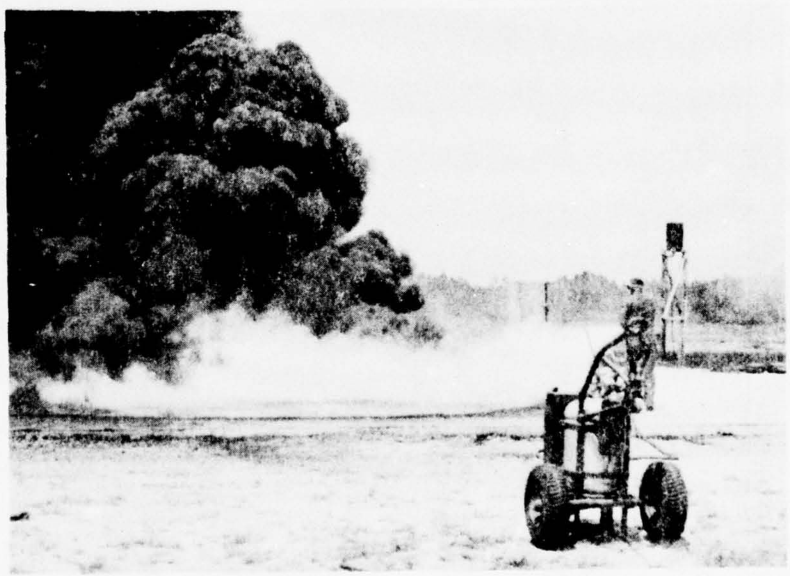


FIG. 33 NOVICE POOL FIRE #6 (AREA 840 FT^2)

FIG. 34 NOVICE AIRCRAFT ENGINE/RUNNING FUEL FIRE

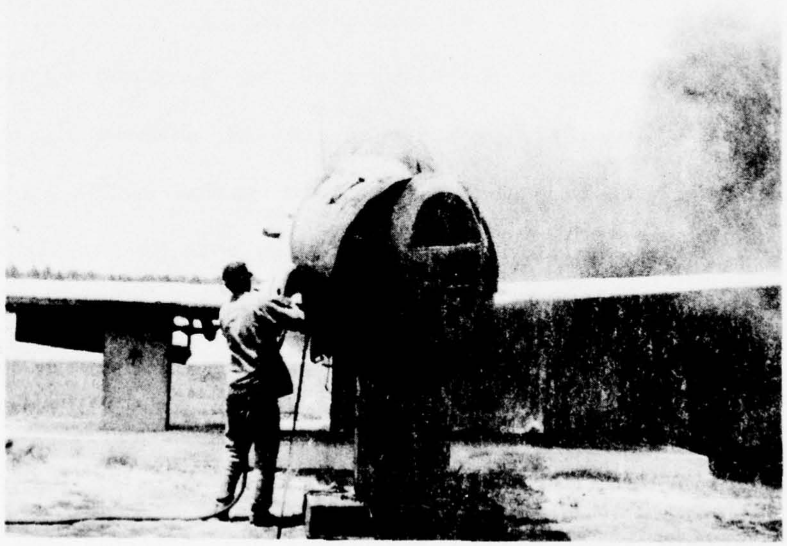


FIG. 35 NOVICE AIRCRAFT ENGINE/RUNNING FUEL FIRE

from the temperature change. A decrease in agent flow rate and distance traveled was noted. However, data analysis (test film and recorded visual observations) showed that test criteria had been exceeded. Therefore, results were satisfactory. During test #2, one extinguisher was repressurized to 175 psig to determine if the practice of adding additional nitrogen pressure at northern bases would significantly increase the agent flow and improve the discharge pattern. Based on the results of test #1, coupled with minor improvement noted in test #2, the procedure for additional pressurization at low temperatures is not necessary. The externally pressurized unit (test #3) proved to be satisfactory.

The extinguisher (not converted) charged with CB agent failed to discharge at -60°F. When warmed to -20°F, a satisfactory discharge was obtained. Reason for failure was not determined and requires further investigation beyond the scope of this program.

Table XIII shows the results of the tests conducted at +140°F. One extinguisher (test #2) pressure relief disk prematurely ruptured at 298 psig when the test chamber temperature reached 145°F. A significant increase in nozzle reaction was noted during both Halon 1211 tests.

5.4 Phase II Results

The existing unmodified CB-10 extinguishers employing CB can extinguish a maximum of 250 to 300 square feet of the type of fuel in-depth fire used during this program.

With the internal pressure configuration and Halon 1211, fuel in-depth fires of approximately 200 square feet were easily extinguished, and it was possible to extinguish two reflashes with the same unit without

TABLE XII

COLD TESTS -60°F

TEST NO.	CONFIGURATION	INITIAL PRESSURE (psig)	RESULTING PRESSURE AT -60°F (psig)	RANGE (FT)	TIME OF DISCHARGE WITHOUT FLASHING (SEC)	COMMENTS
1	ICI (INTERNAL)	200	115	20-30	45	CONICAL PATTERN LESS THAN ONE FOOT IN DIAMETER
2	STOP FIRE (INTERNAL)	240	.120*	30-40	30	CONICAL PATTERN LESS THAN ONE FOOT IN DIAMETER
3	ANSUL (EXTERNAL)	1600**	1200	35-40	52	CONICAL PATTERN LESS THAN ONE FOOT IN DIAMETER
4	STOP FIRE (INTERNAL) CB AGENT	240	150	--	--	EQUIPMENT MALFUNCTION

*INCREASED TO 175 psig FOR DISCHARGE TEST.
**EXTERNAL NITROGEN BOTTLE - REGULATED FOR 175 psig.

NOTE: MAXIMUM DISCHARGE RANGE POSSIBLE WAS 40 FT IN TEST CHAMBERS; ANSUL 0.422 NOZZLE USED FOR ALL DISCHARGES.

TABLE XIII

HOT TESTS +140°F

TEST NO.	CONFIGURATION	INITIAL PRESSURE (psig)	RESULTING PRESSURE AT +140°F (psig)	RANGE (FT)	TIME OF DISCHARGE WITHOUT FLASHING (SEC)	COMMENTS
1	ICI (INTERNAL)	200	273	12-20	43	CONICAL PATTERN FOUR FEET IN DIAMETER AT 10 FEET
2	STOP FIRE (INTERNAL)	240	295	--	--	EQUIPMENT FAILURE
3	ANSUL (EXTERNAL)	--	1500*	15-20	52	CONICAL PATTERN FOUR FEET IN DIAMETER AT 15 FEET
4	STOP FIRE (INTERNAL) CB AGENT	240	282	30-40	40	CONICAL PATTERN TWO FEET IN DIAMETER AT 20 FEET

*EXTERNAL NITROGEN CYLINDER PRESSURIZED TO 1500 psig FOR DISCHARGE TEST - REGULATED FOR 175 psig.

NOTE: ANSUL 0.422 NOZZLE USED FOR ALL DISCHARGES.

recharging. Approximately 300 square feet appeared to be the upper limit for a single fire.

With the external pressure configuration 500 to 700 square feet, fires are easily extinguished by an experienced operator. It is possible to extinguish much larger fuel in-depth fires of the type used in this study with good operator technique.

The converted CB-10 units with Halon 1211 extinguished all tire fires of the type used during this study when the preburn was eight minutes or less. Potassium bicarbonate based dry chemical was ineffective for extinguishing like tire fires. CB was judged to be as effective as Halon 1211 based on limited number of tests conducted.

The converted CB-10 units with Halon 1211 consistently extinguished severely obstructed fires in the engine compartment of a jet aircraft even with fuel flowing as high as seven gallons per minute (higher flows not tested).

Running fuel fires resulting from a simulated severed fuel line and the associated spill fire were easily extinguished when employing Halon 1211.

The converted CB-10 extinguisher (internally pressurized) is capable of consistently extinguishing large spill fires on typical flight line concrete surfaces. With this configuration, fires of approximately 700 square feet (that resulted when a spill of 40 gallons was ignited) were extinguished, and it was possible to extinguish one reflash with the same unit. Approximately 1100 ft^2 appeared to be the upper limit for a single fire.

Novice fire fighters had no difficulty extinguishing simulated flight line fires. Their ability to extinguish spill fires (pool) was reduced when compared to results obtained by the experienced operator.

With flow rates above 6#/sec, the increased nozzle reaction hindered effective agent application. As the flow rate was reduced below 6#/sec, a corresponding decrease in the area of fire that could be extinguished was observed.

The Ansul 0.422 nozzle was found to be the most effective and versatile of all the nozzles tested.

The converted CB-10 extinguishers (internal and external configurations) operated satisfactorily at extreme test temperatures (+140°F and -60°F).

6.0 PROGRAM CONCLUSION

When converted to Halon 1211, the CB-10 flight line extinguishers are remarkably effective on the types of fires likely to occur on or near parked aircraft. The ability of Halon 1211 to extinguish most tire fires and to penetrate through and around jet aircraft engines was considered as good as CB.

7.0 PROGRAM REVIEW

Since the major objective of this program was to determine the most cost effective mechanical conversion of the CB-10 to Halon 1211, particular emphasis was placed on observing how the various configurations performed, ease and cost of conversion, ruggedness, potential for leaks, etc. The following are some important points that should be considered

1. Existing Inventory: Currently there are about 8,000 CB-10 units in service. The majority were manufactured during the 1960's. Although some units are in poor physical condition and might fail a hydrostatic test, the vast majority could be successfully converted to Halon 1211 and remain in service.

2. Clean Agent: The existing CB-10 extinguishers are positioned around parked aircraft and are likely to be used on engine fires, ground APU and electrical equipment fires, tires fires and spill fires. The conversion to Halon 1211 (clean agent) is highly desirable for protection of this mission essential aircraft and support equipment.

3. Operator Training: Novice fire fighters selected from flight line personnel generally demonstrated a poor agent application technique. Some familiarization with the characteristics of Halon 1211 in the form of test fire demonstrations by base fire departments would be required. For example, some novices tended to elevate the nozzle to reach the fireball downwind from the far edge of the fuel. With CB, the liquid continually dropped onto the fuel surface, preventing reflash. With Halon 1211, the vapor was above the fuel surface and reflashes occurred. Typical fireball is depicted in Figure 36.

4. Extinguisher Operation and Nozzle: First aid extinguishers should be conveniently located so that delays in activation are minimized. Complicated extinguishers that are difficult

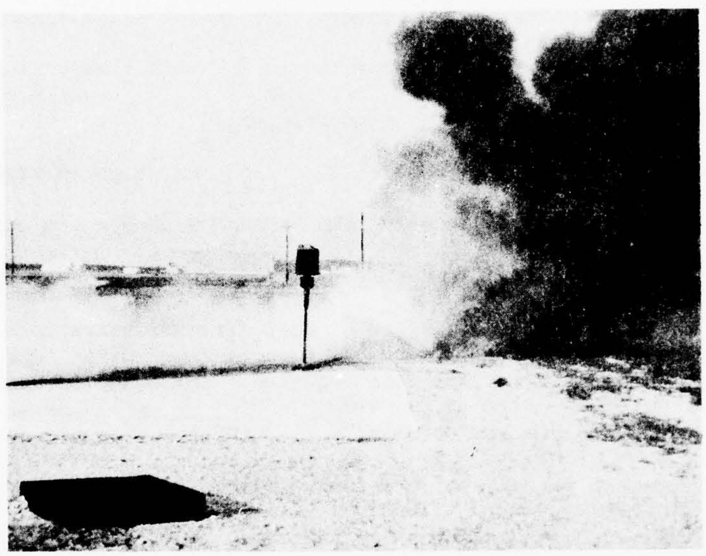


FIG. 36 VAPOR FIREBALL

to place into operation should be avoided. Overly complicated nozzles like the present CB nozzle should also be avoided. It is highly unlikely that a novice fire fighter could successfully accomplish a two or three step charging operation followed by selection of the correct position(s) for a variable nozzle under the emotional stress of a fire situation.

5. Potential for Leaks: Since CB-10 units are stationed outdoors and often abused, the number of connections, piping joints, gaskets, etc, where leaks could occur should be held to a minimum. This is especially true since these units are subjected to vibrations when towed behind a motor vehicle.

6. Extinguisher Size: Wheeled fire extinguishers will most likely be used by flight line mechanics, crew chiefs, pilots, etc, who are not extensively trained in fire fighting. These personnel do not have protective clothing and consideration must be given to the fact that they probably would not risk their own safety by attacking extremely large fires. This would be true even if greater quantities of the fire fighting agent were provided. For this reason, the CB-20 extinguishers (20 gallons) were not converted to Halon 1211. These units are normally positioned near fuel storage facilities where a clean agent is not really necessary, and these CB-20 units are scheduled for replacement by dry chemical and/or aqueous film forming foam (AFFF) extinguishers.

7. Advantages and Disadvantages of Internal Versus External Pressurization:

a. Internal Pressure Advantages:

(1) Lower cost and simplier conversion.

(2) Conversion could be accomplished on base without shipping units to a central location.

(3) Easier to put into operation by untrained personnel.

(4) Less functional components and chances for leaks.

b. Internal Pressure Disadvantages:

(1) Less agent quantity, hence reduced fire fighting capability.

(2) Flow rate and range dropoff as agent is discharged.

(3) Discharge more affected by temperature.

(4) Cannot purge hose from self-contained nitrogen source.

c. External Pressure Advantages:

(1) Greater agent capacity, hence more fire suppression capability.

(2) Longer discharge time.

(3) Constant flow rate throughout discharge.

(4) Can purge hose from self-contained nitrogen source.

d. External Pressure Disadvantages:

(1) More expensive to convert.

(2) Units must be shipped to contractor's facility and/or service center for conversion.

(3) More complicated to operate.

(4) More functional components and chances for leaks.

(5) Increased maintenance costs.

(6) Special equipment needed to fill high pressure nitrogen cylinder.

(7) Extremely difficult to verify pressure in external nitrogen supply.

8.0 RECOMMENDATIONS

1. Mechanically adapt all serviceable FEU-1, CB-10 flight line extinguishers to enable them to utilize Halon 1211 fire extinguishing agent instead of chlorobromomethane (CB). CB has irritating and somewhat toxic effects and is no longer recognized as a fire extinguishing agent by regulatory agencies, including OSHA.

2. Replace only the parts or components necessary to enable the existing CB-10 units to utilize Halon 1211 in the internal or stored pressure mode. Allowing the CB-10 units to remain in an internal pressure configuration is the least expensive. Tests also have shown the converted (Halon 1211) units have sufficient capacity to extinguish a very high percentage of fires likely to occur around parked aircraft. Large spill fires are rare as evidenced by statistics issued by FAA[6], which show that with commercial aircraft most fires occur in engines, tires and support equipment, with only 4% fuel spill fires. When this is considered with the Army survey[4], which

shows that 96% of fuel spills are less than 42 gallons, which a converted unit extinguished twice without refilling, it can be concluded that the internal pressure mode is the most cost effective. A further consideration is that the extinguishers are intended for operation by flight line personnel without extensive training or protective clothing. CB-10 type appliances are designed to control or extinguish incipient fires before the fire department can arrive with primary agents like foam and water.

3. <u>On serviceable extinguishers, replace only the nozzle and operator instructional plates</u>. This will require a filling adapter for each base extinguisher maintenance shop but will be considerably less expensive than adding a fill adaptor to each unit. With this method, converted units would be filled through the main discharge valve instead of the filling cap. Should convenience and ability to rapidly recharge empty extinguishers be judged more suitable, a modified filling cap with a quick disconnect similar to the Stop Fire modification is recommended. Both proposals would use existing P-13 fire truck filling equipment. <u>Note</u>: Even though the recommended configuration was not tested, there would not be any change in extinguisher performance. Discussion with equipment manufacturers and the agent supplier verified the feasibility of this filling method.

4. <u>Replace existing multipattern nozzle with an aluminum nozzle</u>

the same type as the 0.422 unit submitted by The Ansul Company. The Ansul nozzle provided the most consistently effective pattern. Fabrication with aluminum similar to the P-13 Halon 1211 nozzle instead of brass should reduce nozzle cost and the situation that makes them subject to pilferage in overseas locations.

5. When necessary, replace damaged hoses on converted Halon 1211 units with the same style scheduled for inclusion on the new P-13 skid mounted unit. The existing CB hose is necessarily expensive and not required for Halon 1211. However, there is no reason to replace existing hoses that are serviceable.

6. As necessary to meet requirement, purchase new Halon 1211 extinguishers standardized on 150 pounds of agent. New units should have mild steel tanks instead of expensive stainless steel and the nozzle and hose described in recommendations 4 and 5 above. Tank volume should be such that 150 lbs of Halon 1211 occupies 55% of the available space.

7. Initiate projects to evaluate the following:

   a. Conversion of existing CB-20 units (20 gallons) to aqueous film forming foam (AFFF) extinguishers. By replacing the hose, nozzle and operation instruction plates, this unit could easily be converted to AFFF/water and provide a burn-back resistance capability when used in combination with dry chemical units at fuel storage

locations.

b. Replacement of large CO_2 wheeled units currently used on the flight line. Although not evaluated during this program, CO_2 units stationed on the flight line should be replaced by the substantially more effective Halon 1211 units.

REFERENCES

1. S Atallah and R S Stricoff, "Evaluation of Auxiliary Agents and Systems for Aircraft Ground Fire Suppression, Phase II," Arthur D Little Technical Report ASD-TR-73-41, Cambridge, Massachusetts, May 1974.

2. S P Dunn and B C Christensen, "Technical Brief Pertaining to Various Modes for the Conversion of CB-10 Wheeled Fire Extinguishers to Halon 1211," The Ansul Company, 11 Nov 1974.

3. J J Novotny, N Fletcher, and J Ramsden, "An Evaluation of the Effectiveness of the FEU-1/M Mode CB-10 Fire Extinguisher Converted for Use with BCF-Halon 1211," ICI United States, 28 Apr 1975.

4. Lt Col V J Ciccone, US Army, and 1/Lt A P Graves, US Army, "A Study to Evaluate the Intensity of and Alternate Methods for Neutralization of DOD Aircraft Fuel Spills - Phase I," DOD AGFSRS-TR-76-2, Feb 1976.

5. R S Alger and J R Nichols, "A Mobile Field Laboratory for Fires of Opportunity," NULTR-73-87, 3 Oct 1973.

6. W V Vitale, "Cursory Summary of Some Significant Accidents/Incidents Where CFR Coverage was Provided," letter dated 30 Apr 1975, FAA/ Airport Services.